POINT TO POINT

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Points of view

TRANSISTORS figure very much in the news today and for many people, these devices have achieved an almost mystical importance. Whenever new equipments are discussed, the first question that is asked is—'will it be transistorized?'

To use them in portable equipment, or where power consumption is important, is obvious. For many static installations these considerations are not always important and the use of transistors should be considered primarily in terms of the other advantages that may be obtained. Where a reduction in maintenance is considered vital, the use of transistors could be a useful means of achieving this end.

As an example of this approach to transistorization, one could take a receiver of the commercial type—which could be in almost any frequency band. Such a receiver employs a very large number of valves working in complex circuits. These are mounted on fairly big chassis and this fact alone makes maintenance a complex task. Maintenance could probably be simplified if the arrangement of circuits on any one chassis could be broken down into functional units, thus assisting diagnosis and making it easier to replace components or even complete units.

If this is attempted with thermionic valves, it is often found that the space requirement increases and this can bring about other complications. If the frequencies are high, the breaking-up of the equipment into functional units, each one of which is fairly big, often introduces problems of cross-talk or leakage.

If, however, transistors are used, it is more likely that the units can be reduced to small proportions and there are fewer limitations to the shape and physical layout of the unit. Thus, transistors offer the designer an opportunity to break down into small compact units, each one of which is performing a clearly defined function in the equipment or the

system. The use of transistors also lends itself very well to the use of small printed boards for the wiring and in some cases also for the components.

The advent of transistors can therefore make possible a completely new approach to the design of equipment with a view to considerably reducing maintenance required in the field. There is probably little virtue in taking any known electronic or radio device and converting it from the use of thermionic valves to transistors, unless at the same time there is an entirely new approach to the mechanical format of the equipment.

Even so, in changing to transistors we must remember that the small thermionic valve is an extremely reliable device and it would be unwise to render some existing equipment obsolete unless the new design using transistors makes a very substantial step forward in terms of reduced maintenance cost and increased reliability. It is not enough that future designs, using a new mechanical format and transistors, should be only marginally better than those in use today. The step forward must be a massive one which gives a radical improvement.

Designers and manufacturers of high grade radio communications equipment are sometimes mildly criticized for not introducing transistors more rapidly. Herein lies part of the answer. It can well be a case of 'more haste—less speed'. A.W.C.

On the end of a chapter

ON 6TH JULY 1960, a chapter of Marconi history came to a close. At a private ceremony held in Marconi House, London, Lord Nelson of Stafford, Chairman of Marconi's Wireless Telegraph Company Limited, presented the title deeds to some 40 acres of land at Poldhu, in Cornwall, to the National Trust,* thus severing the last physical link between the Marconi Company and the world-famous radio station which had formerly existed on this site. In view of the vital rôle played by Poldhu in the story of point-to-point communication, it seems appropriate to mark the occasion by a brief note on its history.

In June 1896, at the age of 22, Guglielmo Marconi filed his first patent, and in the following year his Company was formed. During the next three years, many practical demonstrations were given, and the British Admiralty sufficiently impressed to order equipment. These demonstrations had all taken place over comparatively short distances. Eminent scientists, basing their opinion on the known similarity of the properties of wireless waves to those of light waves, were convinced that the curvature of the earth would limit their range approximately to the optical horizon, no matter what power was employed, even allowing for the long-established diffraction effect. Professor Popoff, a distinguished contributor to the early experimental art of electro-magnetic wave generation and propagation, belonged to this school of thought as late as 1901. (There is no doubt that he did not appreciate the significance of

* The National Trust is a private body formed in 1895 to preserve places of historic interest or natural beauty in the United Kingdom.

The ceremony held at Marconi House in the Strand when the title deeds of the Poldhu site were handed over by Lord Nelson of Stafford to Earl De La Warr of the National Trust. Left to right: Sir Godfrey Ince, Chairman of Cable & Wireless Ltd, Sir Ronald German, Director General of the G.P.O, Lord Nelson of Stafford, Earl De La Warr and Mr C. S. Franklin

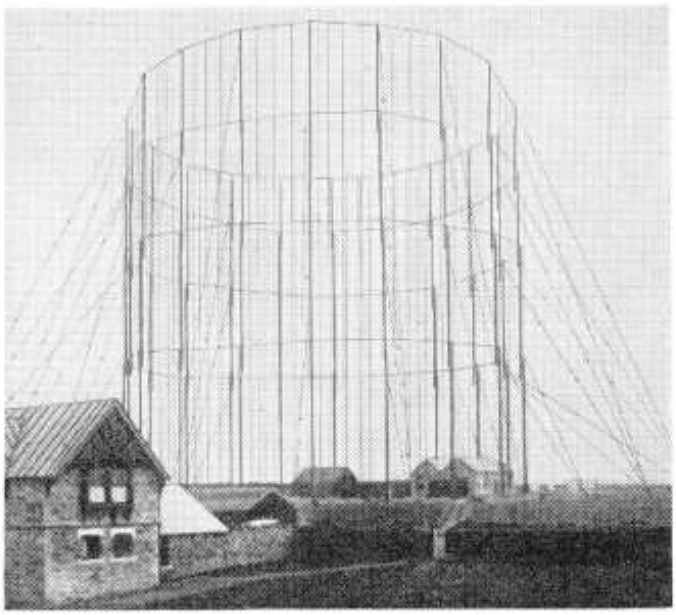
the vertically polarized ground wave, on which the success of Marconi's experiments was based, for long distance propagation.) At the same time as established scientists expressed their caution, other inventors and imitators were putting forward counter claims.

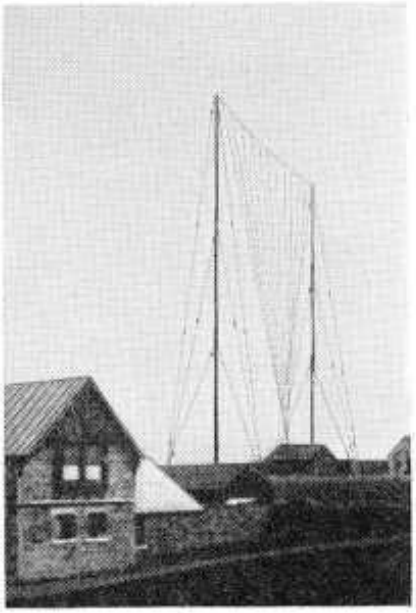
It was in this controversial atmosphere that Marconi decided that the future of wireless telegraphy as a medium for long distance communication could only be assured by a convincing and dramatic demonstration of its potentialities. He decided that nothing less than to bridge the Atlantic would meet the situation.

For there to be any chance of success it was apparent that an unobstructed oversea path was essential. Cornwall, in the South West of England, must have quickly suggested itself as a location, and the ideal site was found at Poldhu Point, a few miles north of the Lizard, near the

small village of Mullion. Construction of the station buildings began in October 1900. Professor J. A. Fleming, F.R.S, a well-known authority on high-tension alternating current work, and later the inventor of the thermionic diode, had been appointed scientific adviser to the Marconi Company and was mainly responsible for the design of the transmitting equipment. At the time there was no technique available for the accurate measurement of power and wavelength at high frequencies, but the evidence suggests that the power to the aerial was probably about 10kW, and the wavelength somewhat less than 2 000 metres. In any event, the transmitter power was of the order of 100 times greater than anything previously attempted, so that considerable problems had to be faced. Nevertheless, the equipment was ready for preliminary trials by January 1901.

The first long-distance tests, using a temporary transmitting aerial, were carried out between Poldhu and Crookhaven, 225 miles (360km)

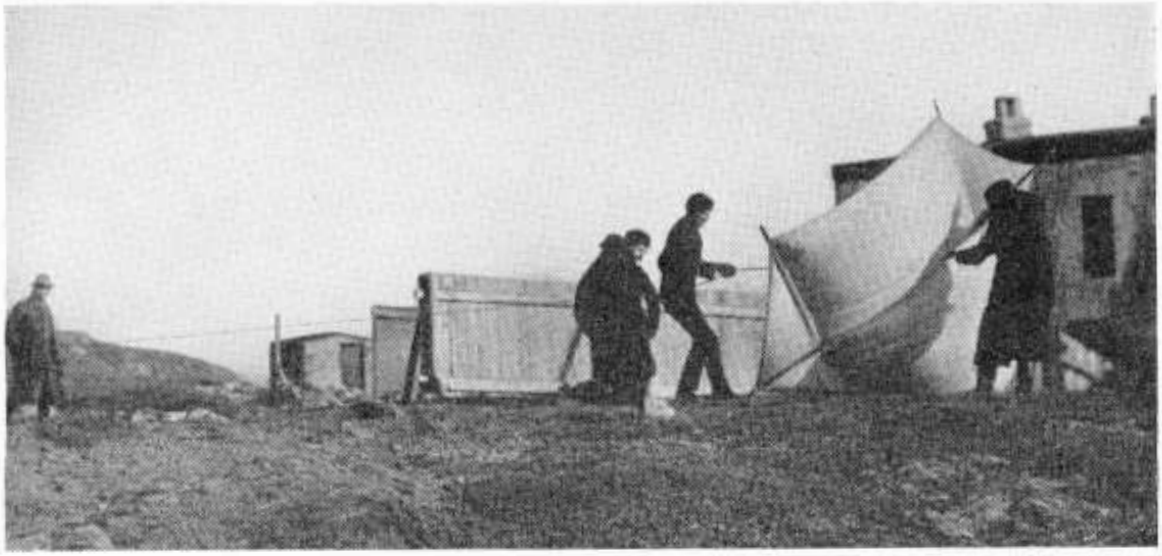




LEFT: *The aerial system originally erected for the Transatlantic test consisted of twenty 200 foot masts erected in a circle. It was wrecked by a gale shortly before the experiment was made*

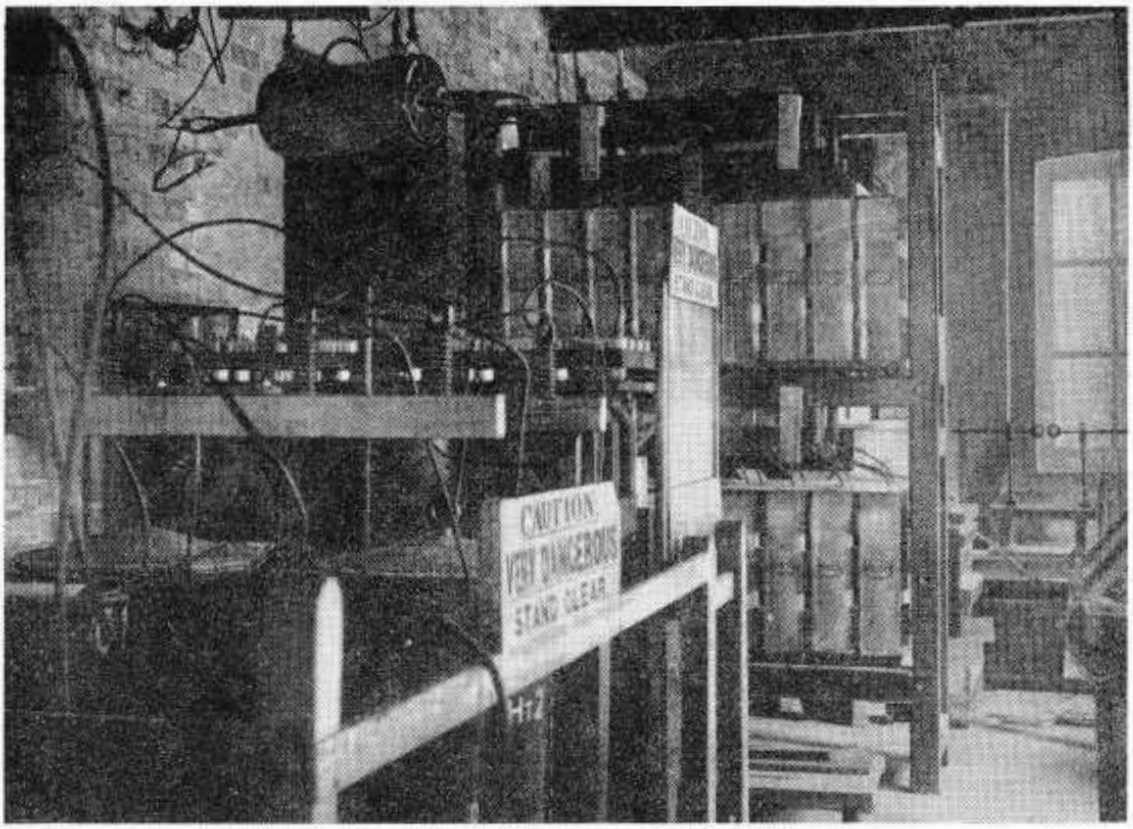
RIGHT: *The 150 foot masts supporting a 60 wire fan-shaped aerial which replaced the original circular system intended for the Transatlantic experiment*

away on the west coast of Ireland, and were very successful. Work continued but on 17th September there was a serious setback when a heavy gale destroyed the aerial and mast system intended for the Transatlantic test. It was replaced by a less elaborate aerial consisting of a vertical fan of 60 wires suspended between two 150 foot masts. After all was ready at Poldhu, Marconi sailed for Newfoundland on 27th November with his two assistants, Kemp and Paget, arriving on 5th December.



Erecting the kite aerial at Signal Hill, Newfoundland, in readiness to receive the first Transatlantic wireless signal, December 1901

By 9th December, their preparations for a temporary receiving station at St John's were sufficiently far advanced for instructions to be sent to Poldhu to begin the transmission programme on the 11th. This was to consist of continuous repetitions of the Morse letter 'S' between 3 and 7 p.m. GMT. The next day was spent in experiments with kites, as purely temporary means of supporting the aerial were to be used, and one was successfully flown with 600 feet of wire. It was found that variation of the aerial capacity as the kite rose and fell prevented the effective use of tuned circuits, so Marconi decided to fall back on reception with a



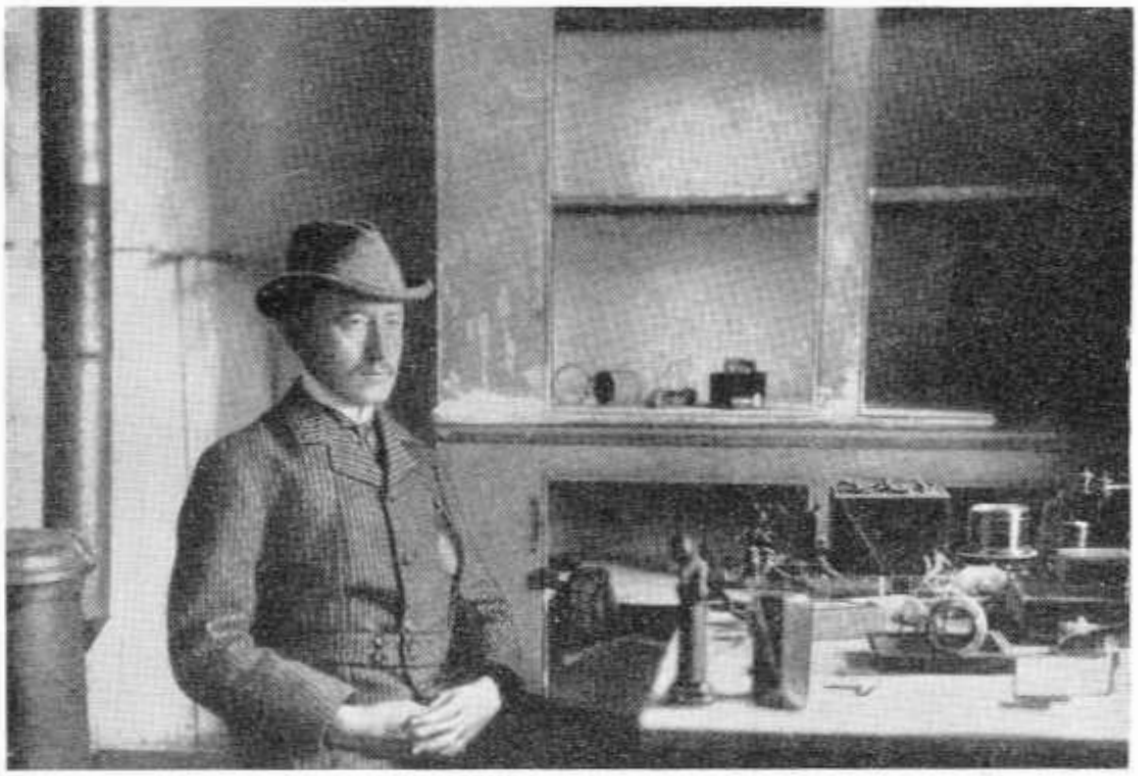
The transmitter at Poldhu with which the first wireless signal was transmitted across the Atlantic

self-restoring mercury coherer and telephone earpiece, transformer-coupled to the aerial circuit.

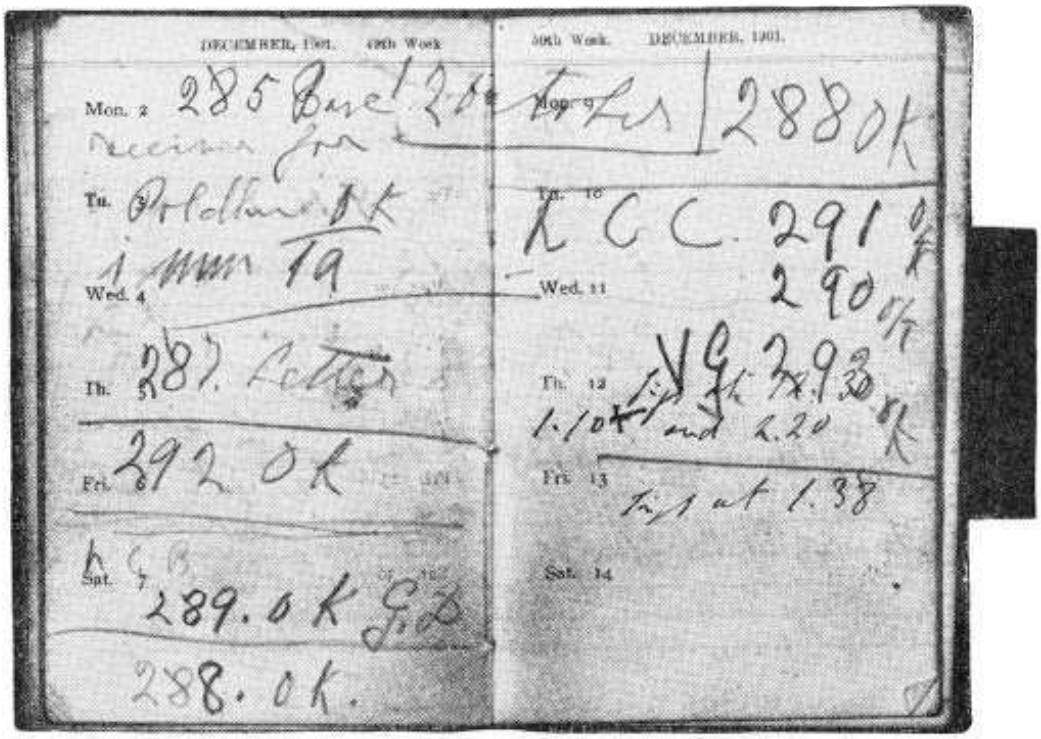
On the 11th December, when the transmissions began, an already strong wind increased in force and a balloon which was to be used for supporting the aerial was carried away and lost. It was decided to try again with kites on the following day, Thursday, 12th December. This time, after losing one kite in a squall, the second attempt was successful and faint but unmistakable signals were first heard, by Marconi and Kemp, through the atmospherics, at 12.30 p.m. local time and again at 1.10 and 2.20 p.m. In the light of present-day knowledge of propagation conditions, and considering the crudity of the apparatus used and the magnitude of the difficulties experienced, it was a great achievement to gain success on only the second day of transmission.

However, there was to be much hard work and many disappointments before the system was developed to the point of commercial success. A more powerful station than Poldhu was constructed on the Canadian east coast at Glace Bay, Cape Breton Island, and for a time Poldhu became the receiving station. It was found possible to transmit coherent messages, although frequent repetition was necessary and the first official messages to receive publicity were sent on 20th December 1902, addressed to the Kings of Great Britain and Italy. Improvements were continuously being made to the equipment, and by August 1903 Poldhu was transmitting again. The indications were that still more power and still lower frequency, necessitating bigger aerials, were necessary to provide a reliable service.

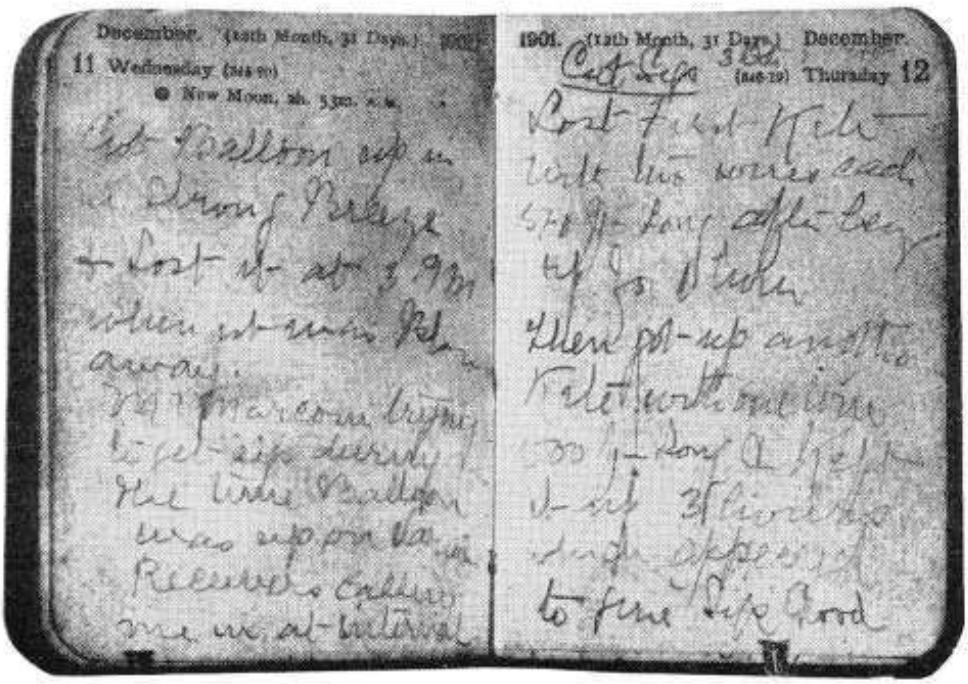
By the time a public Transatlantic telegraph service was inaugurated at the end of 1907, operations at the eastern end of the path had been



Marconi at Signal Hill with instruments used to receive the first Transatlantic signal



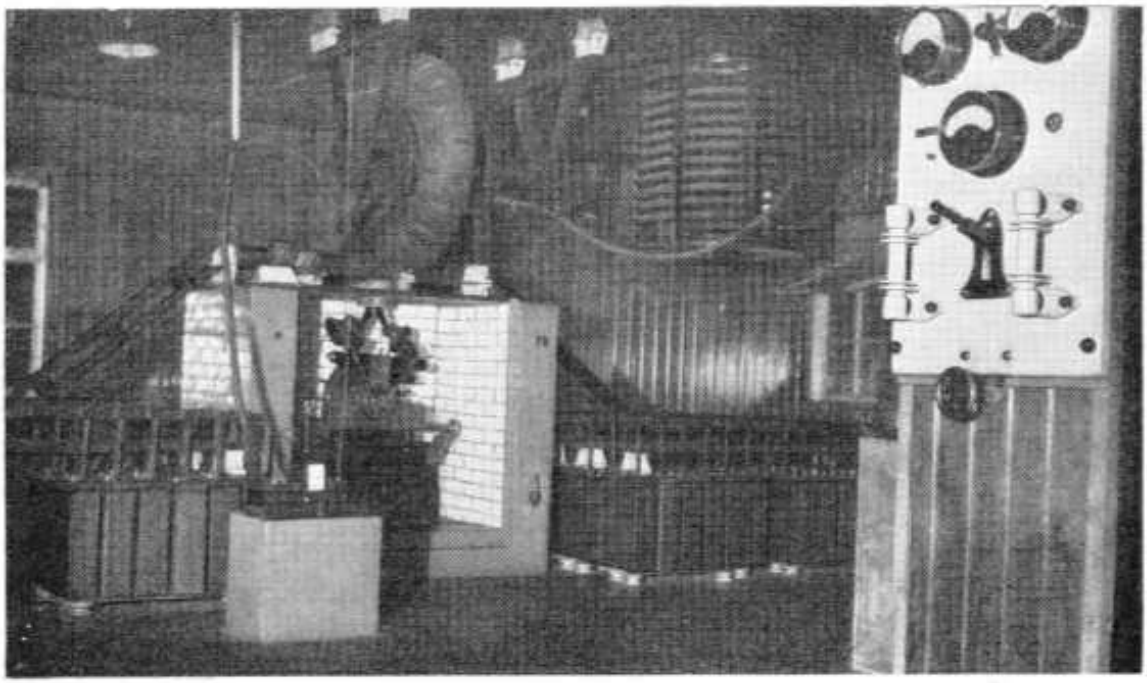
The entries in Marconi's diary for 12th and 13th December, 1901, are in ink, the pencil notes which appear over the original entries relate to subsequent experiments



The entry in Kemp's diary recording the success of the Transatlantic experiment

transferred to Clifden in Ireland, where more space was available and the range somewhat reduced. Meantime, in 1905 Poldhu became a commercial telegraph station in communication with other Marconi stations in Europe and serving ships on the Transatlantic routes with news, commercial, private and navigational messages.

Poldhu continued in this rôle until the outbreak of war in August 1914. During this period the equipment was kept in step with the latest developments. The original 150 foot stayed masts were replaced in 1902 by four 210 foot wooden towers, supporting an aerial system in the shape of an inverted wire pyramid. Steel tubular masts were erected in 1912. The original transmitter had two oscillatory circuits in series, each with its own fixed spark gap, but one of these was soon removed. This transmitter was shortly afterwards replaced by one employing Marconi's rotary spark gap, more constant in action than the fixed gap, but still giving a very rough note. By 1912 the synchronous spark apparatus was in use, developing the familiar steady musical tone with



The Poldhu transmitter by 1914

which the station came to be identified. When war began, Poldhu, in common with other of the Marconi Company's communications stations, was placed under Government control. With its staff supplemented by Services personnel, it played a particularly vital part in maintaining communications with the Atlantic convoys, and was also used each night to broadcast official news bulletins. After the war the station reverted to its pre-war rôle, but obsolescence of the equipment led to its closing down in June 1922.

Meanwhile, there had been developments in connection with the 'commercially useless' short waves of 200 metres and under. In 1920 C. S. Franklin set up a telephone circuit between Hendon and Birmingham on 15-metres, which worked very well for many hours a day. About the same time Captain Round was in charge of tests between Southwold and Holland on 100 metres. British and American amateurs organized tests in 1920 and 1921 with the object of discovering whether 200 metre waves would span the Atlantic by night. In December 1921 a score of U.S amateur stations were identified in the British Isles, one of which succeeded in transmitting a complete message.

Despite the great interest aroused at the time, these results were soon dismissed by the commercial interests as of no lasting value for long-distance communications. Again it was Marconi, without any theoretical support, who had the breadth of vision to put the matter to the test. In 1922 he decided to carry out extensive trials, using Poldhu for transmitting and his yacht *Elettra* for receiving. C. S. Franklin was put in charge of the transmission arrangements, which were to commence with a 97-metre wave. The results were spectacular, particularly when, during the second cruise of the *Elettra*, signals of a wavelength of 32 metres were received in September 1924, both day and night, at Beirut, a range of 2 400 miles. Marconi had also made arrangements for associates in Argentina, Brazil, Australia, Canada and the United States to attempt reception, and again the 32-metre signals from Poldhu were received successfully, for prolonged periods, in all those places.

These remarkable results convinced the Marconi engineers that short-wave communication using directional aerials represented a practical alternative, more efficient and at a fraction of the cost, to the extensive

The granite column erected to commemorate the site of the former wireless station

scheme of long-wave high-power stations for Imperial Communications, on which work had already started. It would need much more space than is available here to tell the story of the resulting negotiations, but the result was that by 1927 short-wave 'Beam' transmission was in operation between England and the principal parts of the world at a telegraph speed that no long-wave or cable system had ever approached.

Much of the research and engineering work for the 'Beam system', particularly on the aerials and feeders, was carried out at Poldhu in the period 1924-27 under the direction of C. S. Franklin. It was there that the first tests of a flat beam aerial were made on 4-metres wavelength

and there also that the coaxial RF feeder was born, as a by-product of the difficulties experienced in using balanced twin-wire feeders for high power.

After the acceptance of the Beam stations, Poldhu continued to be used for research and development work. Tests were made with wavelengths down to 8-metres using a revolving beam aerial, and readable signals to New York obtained for five hours out of the 24. The last important development was that of the Series Phase Aerial in 1932. Shortly afterwards, no doubt hastened by the depression, the decision came to close down the station, whose existence for research purposes could no longer be justified in view of its remote situation. In 1937 some six acres of land along the cliff edge, together with a granite column commemorating the events described above, were presented to the National Trust. The recent bequest is the remainder of the Marconi Company property in the area.

We are again approaching a time when fundamental changes may occur in the means used for long-distance radio communication. Apart from its historical interest, the story of Poldhu, linked with that of Guglielmo Marconi, has shown that a bold approach, breaking if necessary with existing techniques and beliefs, can lead to great advances.

Telemetering and Remote Control over Radio Links

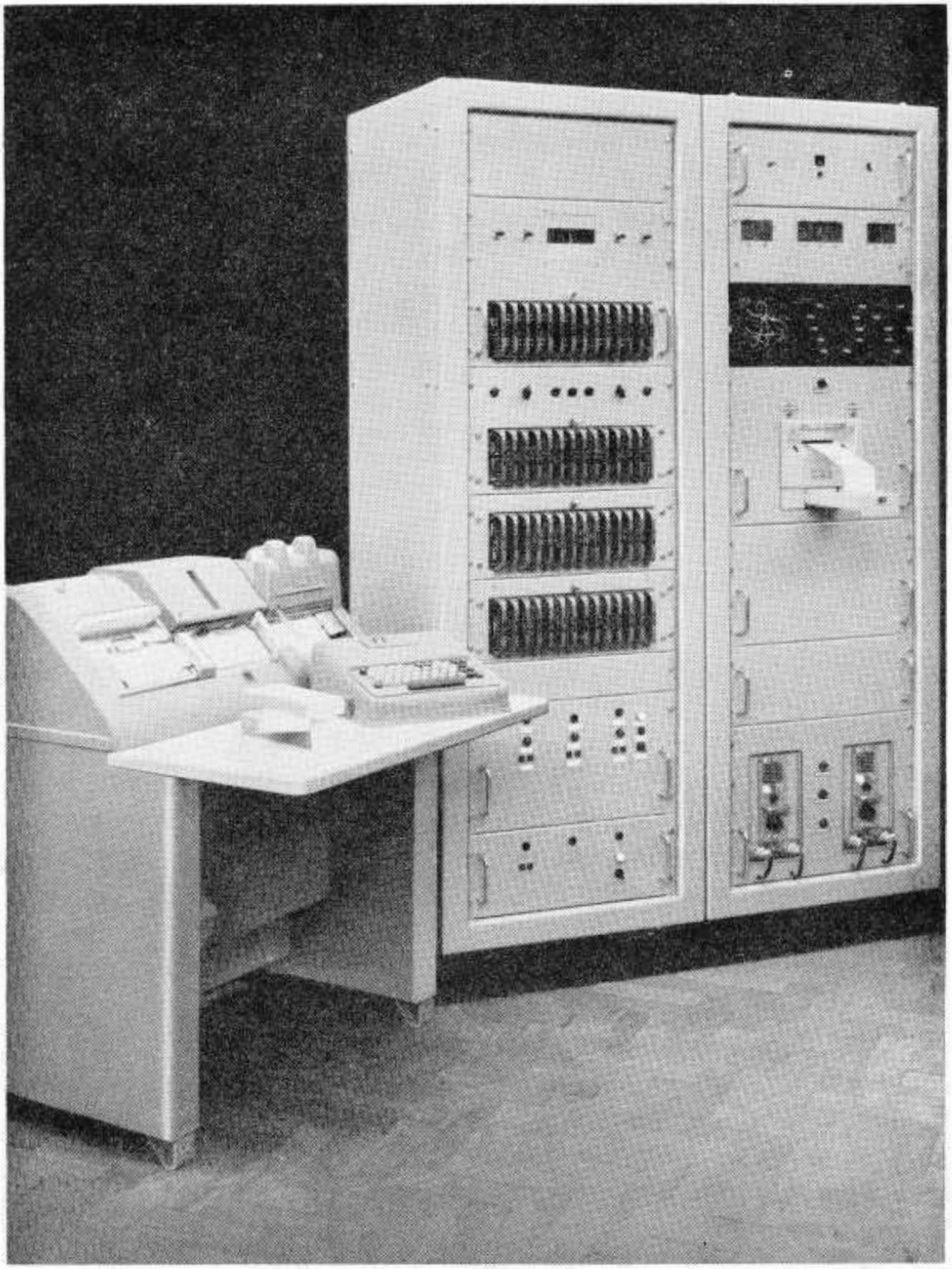
S. SKOUMAL, Dipl-Ing, A.M.I.R.S.E

The transmission of data over radio links for various purposes is rapidly increasing. One application which is becoming important is the transmission of telemetry and control information. In view of the increasing use of automatic techniques, this article will be of considerable interest.

1 INTRODUCTION

IN THE LAST FIFTEEN YEARS or so telemetering and remote control has reached a new position of prominence in industrial development. The basic concepts, however, date right back into the last century when the first devices appeared. With mechanical engineering well in the lead of technical progress, these devices were of purely mechanical construction, consisting mostly of a system of rods, pulleys, chains, etc. Operation of signals and switch points from signal-boxes on the early railway installations can be mentioned as a typical example. The arrival of electricity on the industrial stage brought about the first revolution, particularly in remote control; all sorts of devices based on the remote operation of an electromagnet were brought into being.

Between the wars steady, but by no means spectacular, progress was made. The concept of servo-systems was formulated but the application of the techniques remained limited mostly to public utility undertakings such as power distribution, public lighting, railway yards, etc. The remotely controlled operations were mostly simple change-overs from one condition to the other and were accompanied by simple forms of telemetering to indicate the state of the device. The complexity of the



Typical telemetery control room equipment

systems came mainly from their size, and concerned only the means of selecting the required points. The difficulties were met quite satisfactorily by well tried techniques borrowed from the telephone industry. The connection between the operator and the remote point was invariably provided by a pair of wires, as the application of radio was not yet generally appreciated.

Post-war developments constitute the second and by far the greater revolution in this field. The process which was started in the framework of war-time effort never stopped. The provision of telemetering and remote control equipment for a wide variety of applications has become an industry in its own right, based on theoretical foundations drawn from cybernetics and communication theory, and now plays an important part in defence, data transmission, in the oil industry (for pipeline or refinery control) and in all kinds of manufacturing processes, in transport and elswhere. The increased demands on accuracy, speed of operation, reliability and size, brought electronic techniques into the field, and the volume of information to be transmitted over substantially increased distances, sometimes involving ground-to-air communication, involves radio links as an integral part of the system. The complexity of the systems, quite substantial already, is bound to increase, particularly when a computer is used as the central decision-making agency for a complicated system.

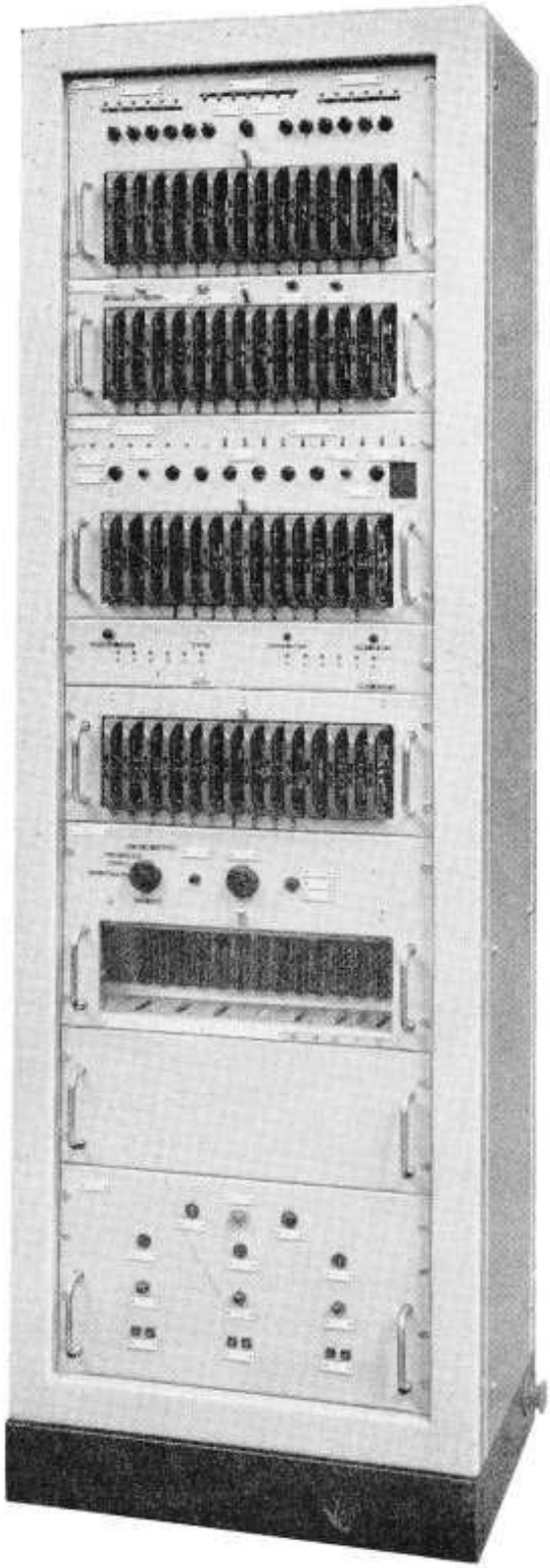
The modern telemetering system must be designed and built as a communication link between computer and outstation.

2 GENERAL CONSIDERATIONS

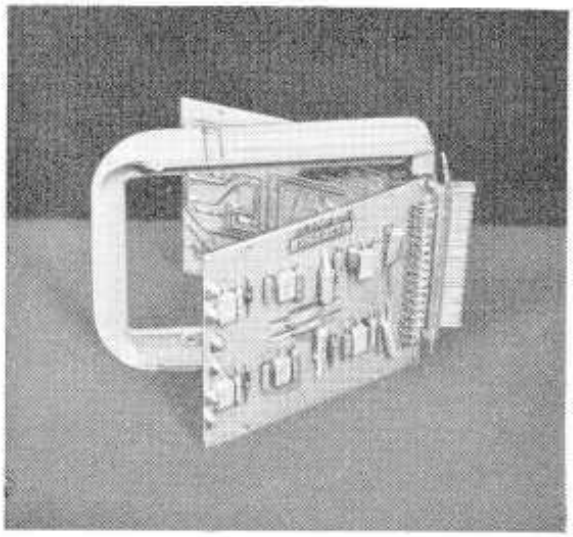
2.1 TELEMETERING AND REMOTE CONTROL

In principle, telemetering and remote control are two rather complex but entirely independent functions of what may be a single system. They are complimentary to each other in the sense that together they form a closed control loop. Telemetering provides the means of gathering information from a remote location, and transmitting it, either continuously or on demand, to a control room.

Remote control is the feedback loop whereby the distant equipment is controlled in response to information supplied by the telemetering



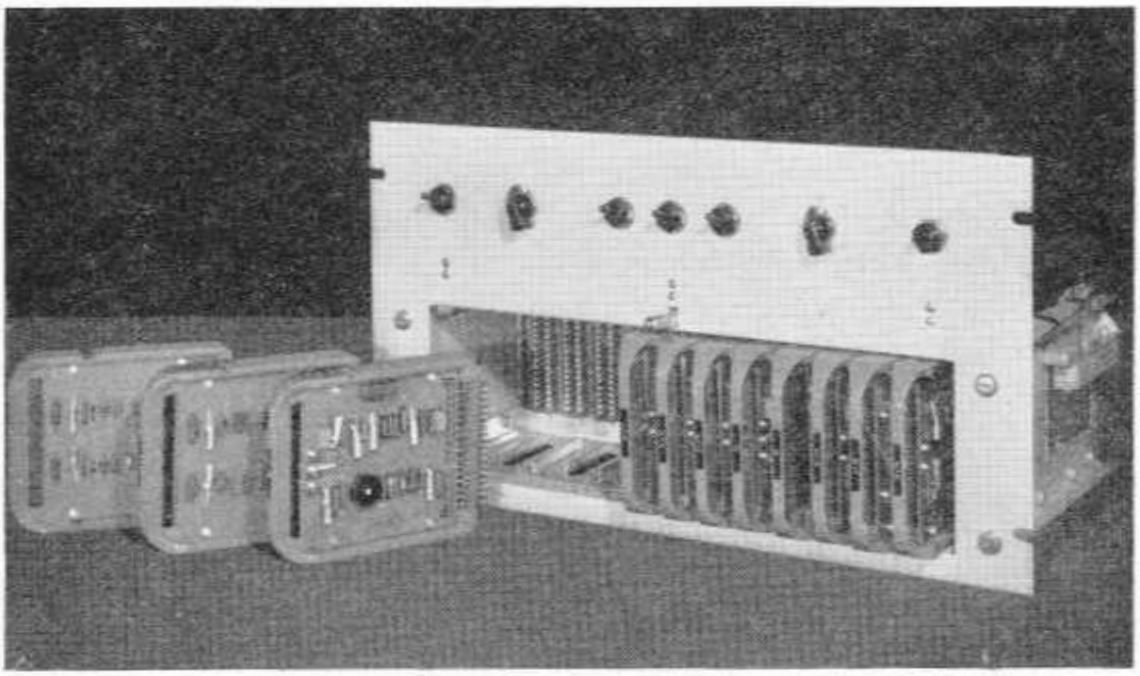
RIGHT: *Typical outstation telemetery transmitting equipment*



Typical telemetery module. Modular construction based on printed boards and transistors is well tried in the computer field and gives trouble-free service over long periods

system. This control can be either manual or automatic. At present the automatic control loop is confined almost entirely to systems where the controlled and the controlling equipment can be connected by a line, while systems using radio links are mostly manually operated. With the advent of self-optimizing installations (i.e, installations designed to find the optimum settings for the operational parameters automatically) automatic readjustment of the control mechanisms will be required in response to the telemetered data (this is, of course, the essential characteristic of an automated installation).

In a complex installation the transformation of the data into a control command is a process which may require solution by an electronic computer. To make the best use of its services, it is visualized that a single computer will control several outstations, and consequently will be situated in some central position, remote from all. Such an arrangement will require communications links of guaranteed accuracy if incorrect decisions are to be avoided.



Arrangement of telemetery modules in a rack

2.2 ANALOGUE V DIGITAL SYSTEMS

The choice between an analogue and a digital principle of operation primarily affects telemetering systems. The pros and cons of both types of system are numerous, and vary with each. However, some of the characteristics, such as accuracy, speed of operation, flexibility, application of error detection techniques, and equipment economy, can be discussed in general terms.

In modern industrial telemetry, the measured quantity is converted at the input of the system into a steady AC or DC signal by the sensing element. In a digital system this signal is further converted into a train of pulses or binary digits (bits) before transmission, whilst an analogue system transmits the signal directly to the display instrument, where the measurement is shown or recorded as a function of its level. The difficulty in detecting the level with the required accuracy in the presence of noise makes analogue systems unsuitable when a transmission link intervenes between the point of measurement and that of display. Digital systems, on the other hand, are largely free from this limitation, their accuracy being a function of the number of bits transmitted for each measured quantity. Moreover, it is possible in a digital system to transmit different parameters from the same outstation using characters containing different numbers of bits, dependent on the accuracy required. This makes the digital system very flexible in application, and economizes in the overall transmission time from each outstation. Further, the digital system can be provided with protection against errors by simple means, cheap in both the extra equipment required and the extra transmission time involved.

Lastly, sight must not be lost of the fact that the demand for the presentation of telemetering data in digital form (such as 'in-line' indicators, electric typewriters, lineprinters, etc) is on the increase. In such systems no advantage could be gained by transmission of signals in an analogue form and the choice between an analogue and a digital system does not arise.

It can be concluded that the usefulness of analogue telemetering systems is limited to cases where a slow-speed low-capacity system is required to operate over short distances with analogue displays.

2.3 CHOICE OF SYSTEM TECHNIQUES

To gain full advantage from a digital system, each piece of information (referred to from now on as a character) comprises combinations of two binary digits, namely 0 and 1. Each bit can be conveniently represented by one of two possible states of the amplitude, frequency or phase of an AC signal, according to the type of modulation used. Thus, each character will be presented to the receiver as a series of amplitude changes, or as a series of frequency or phase reversals.

In order to make economical use of the transmission path, telemetering information from individual points at an outstation is generally transmitted using time division multiplexing. This is possible when some delay in communication between outstations and the control room is not of overriding importance.

When time division multiplex is used, the telemetering transmitter and receiver must be maintained in synchronism, and either synchronous or start-stop operation can be used. The chief advantages of synchronous operation are the greater protection against distortion, and the increased transmission speed due to the absence of start and stop bits. However, where more than one outstation is involved, the different transmission times, resulting from the different distances to the control centre, may require individual telemetering receivers for each remote transmitter.

This economic disadvantage is avoided when start-stop operation is employed. The telemetering receiver is then entirely under the control of the outstation transmitting at the time, and a single receiver can serve any number of them. Also, by adding start and stop bits at the beginning and the end of each character, transitions of polarity marking the beginning of each character occur at regular intervals, easing identification and stability problems. The greater vulnerability to the effects of pulse (or bit) distortion caused by the transmission path is not significant, since high quality radio circuits are normally available in telemetering and telecontrol schemes.

It can be concluded, therefore, that for wide application, a telemetering system should use binary signalling with time division multiplex. Start-stop operation should be used to maintain synchronism between the terminal equipments.

2.4 TRANSMISSION ACCURACY

The importance of avoiding transmission errors has already been mentioned. Errors may arise through noise or impulse interference on the comunication link, and therefore some form of protection is desirable. By virtue of the frequency with which readings are taken from individual points, and because of the relatively low speed at which control needs to be performed, simple error detection is sufficient at present and may be performed by the addition to the character of a checking, or parity, bit, the polarity of which is such as to make the total of one polarity either even or odd, irespective of the content of the remainder of the character. All single and some multiple errors can then be detected by simple 'bit' count. As the links likely to be used for telemetering circuits are generally engineered to give a signal-to-noise ratio of better than 40 dB for at least 99.9% of the total operating time, the residual character error rate will be substantially less than 1 in 10^6.

Although rare, an undetected error can have serious consequences when it occurs. This is particularly true when selection of one of the remotely controlled points at an outstation is concerned. To guard against this type of error, all remote control operations should be executed in stages with confirmation at the control room by means of revertive checks at each stage

2.5 COMPOSITION OF THE CHARACTER

Each group of bits is known as a character. In a complete system three kinds of characters are involved; according to the nature of the information they convey, they can be referred to as metering, alarm or control characters. They are all identical in composition, and vary only in information content.

In order to retain flexibility and to ease the design of the coding and decoding circuits, a binary decimal code is preferable. Thus four bits can represent each decimal digit of the message, so that a two-digit message consists of eight, and a three-digit of twelve, bits of information. An accuracy requirement of 1 in 100 or 1 in 1 000 is most frequently encountered and, therefore, either 8 or 12 bits is the normal information content of the metering characters. To provide protection, as

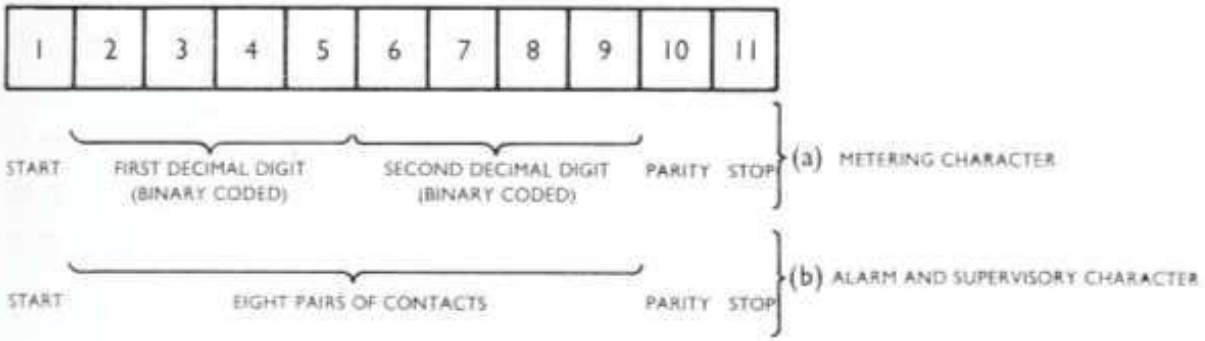


Fig.1. Composition of 11-bit character

discussed in Section 2.4, a parity bit is added to each character before transmission. Lastly, start and stop bits are added. Thus a complete metering character will usually consist of 11 or 15 bits (Fig.1a).

From the transmission point of view an identical character is produced if, instead of taking the 8 or 12 bits from the coding circuits, 8 or 12 pairs of alarm contacts are examined. Such a character is then referred to as an alarm character (Fig.1b). Each information bit of this character then controls one display light on the control panel or a mimic diagram of the system at the control room. The supervisory signals, and signals confirming the selection of the remote control point, are also transmitted by means of these characters.

Control characters are made up in the same way as previous types; normally an information content of only 4 or 5 bits is required, according to the number of control points at the outstation. The purpose is merely that of selection of a particular point prior to performing the required operation.

2.6 SYSTEM OPERATING SPEED

The measure of the telemetering speed is the time which elapses between two successive reports from a particular telemetered point. This period depends equally on three factors:

(i) Length of the metering character
(ii) Number of telemetered points in the scheme
(iii) Telegraph speed of the transmission path.

While the design of any system should retain maximum flexibility,

certain parameter values are more frequently encountered than others. The length of the metering character will depend on the accuracy required. The average number of telemetered points at any one outstation is in the neighbourhood of 10. The number of outstations in a scheme varies considerably, and 10 represents a scheme of reasonable size. The speed of the telegraph channel is usually chosen to be 50 bits per sec, but the design of the driving circuits should be such that other transmission speeds could be used.

Thus, taking as an example a ten station scheme, each requiring metering of 10 points to an accuracy of 1 in 1000 over 50 bits/sec channels (duration of 1 bit = 20 m.sec) the interval between measurements will be $10 \times 10 \times 15 \times 20 \times 10^{-3} = 30$ secs. This is sufficiently frequent for most applications at the present time, but can be substantially reduced where necessary. Either a faster channel can be used or the outstations can be divided into groups, and each group regarded as an individual system, the correct decision depending on the particular scheme.

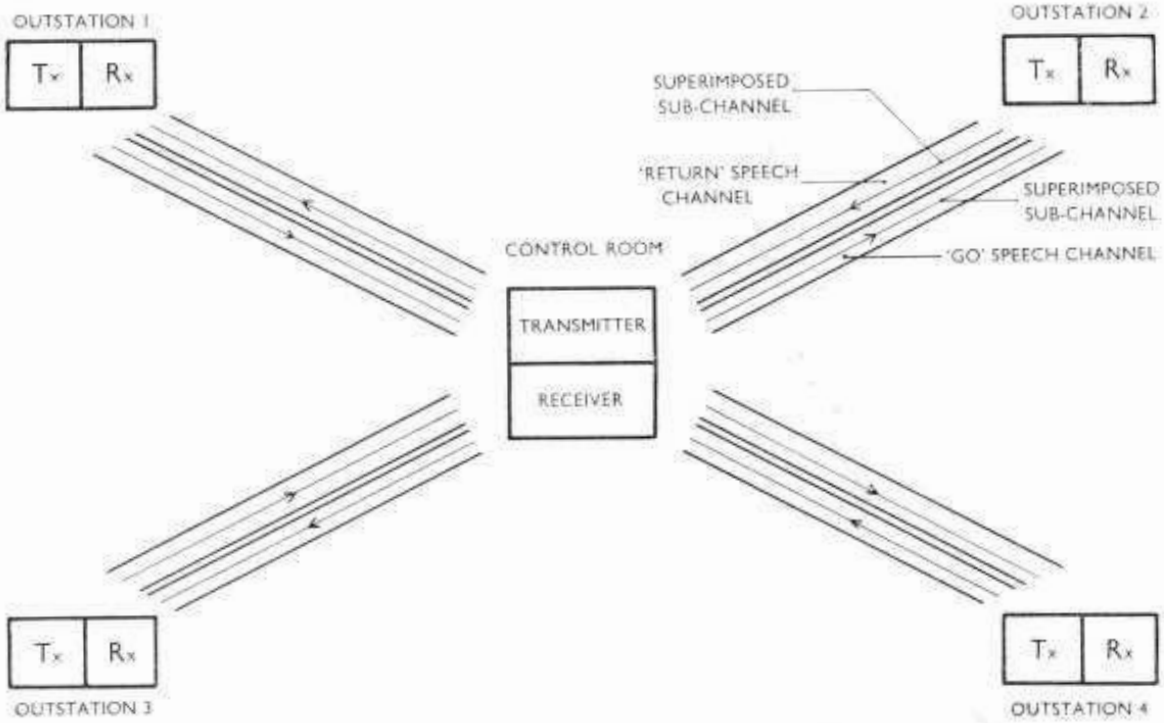


Fig.2. Radial arrangement of four outstations

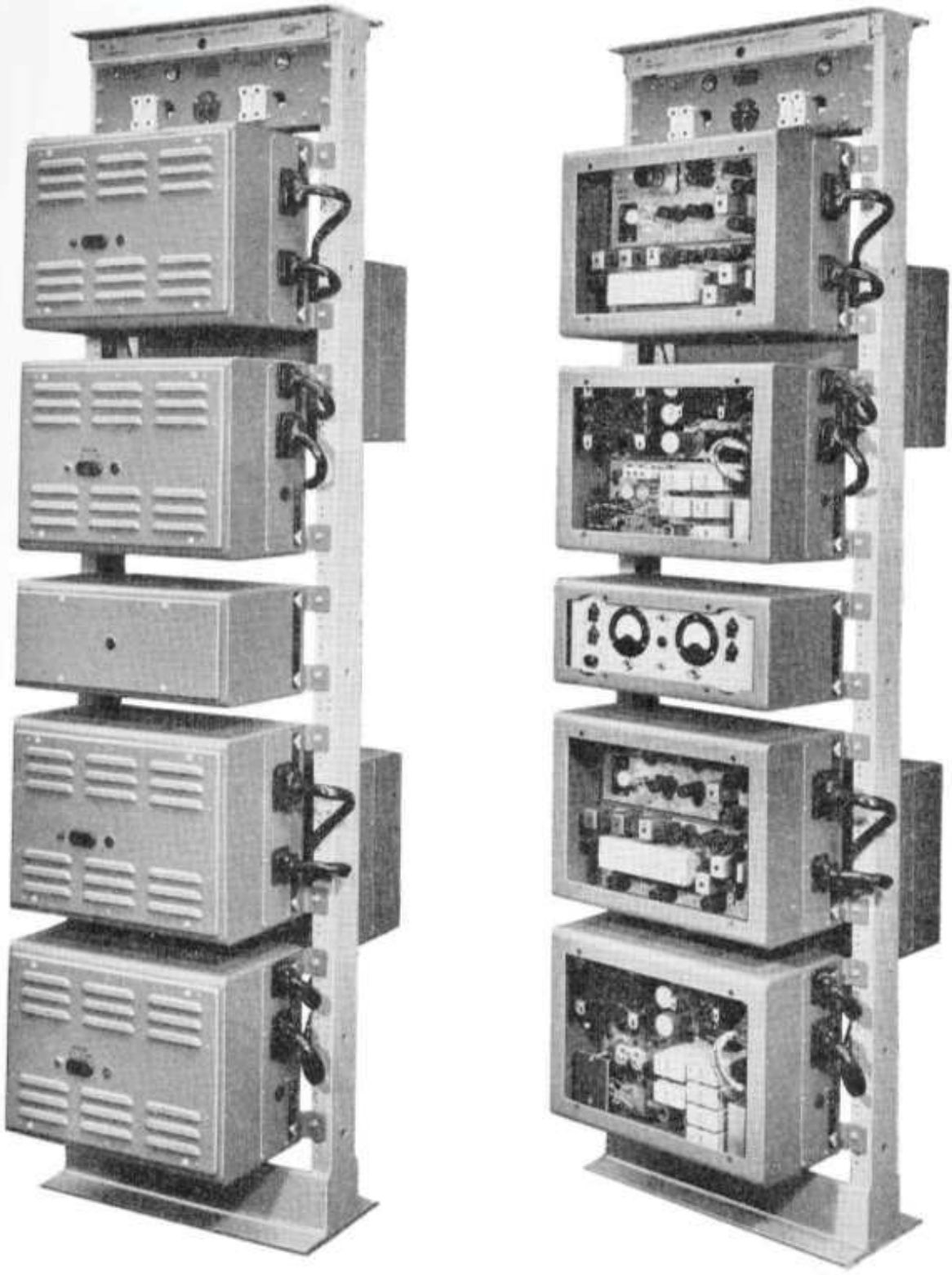


Fig.3. Typical single channel radio equipment
(courtesy A.T. & E (Bridgnorth) Limited)

3 COMMUNICATION SYSTEMS IN TELEMETRY AND TELECONTROL SCHEMES

A standard 50-baud telegraph channel is the most convenient transmission medium for a telemetry system. Where adequate telephone communication links exist between the control centre and the controlled points, it is frequently possible to superimpose the telegraph channel within the speech band of the telephone link. The precise arrangement will depend on the arrangement of the system. In general, this takes one or two basic forms:

(i) When outstations are situated radially from the central control room (such as in process plants, local public utilities, oil fields, refineries, etc).

(ii) When outstations are placed along a definite route (such as pipelines, distribution networks, etc).

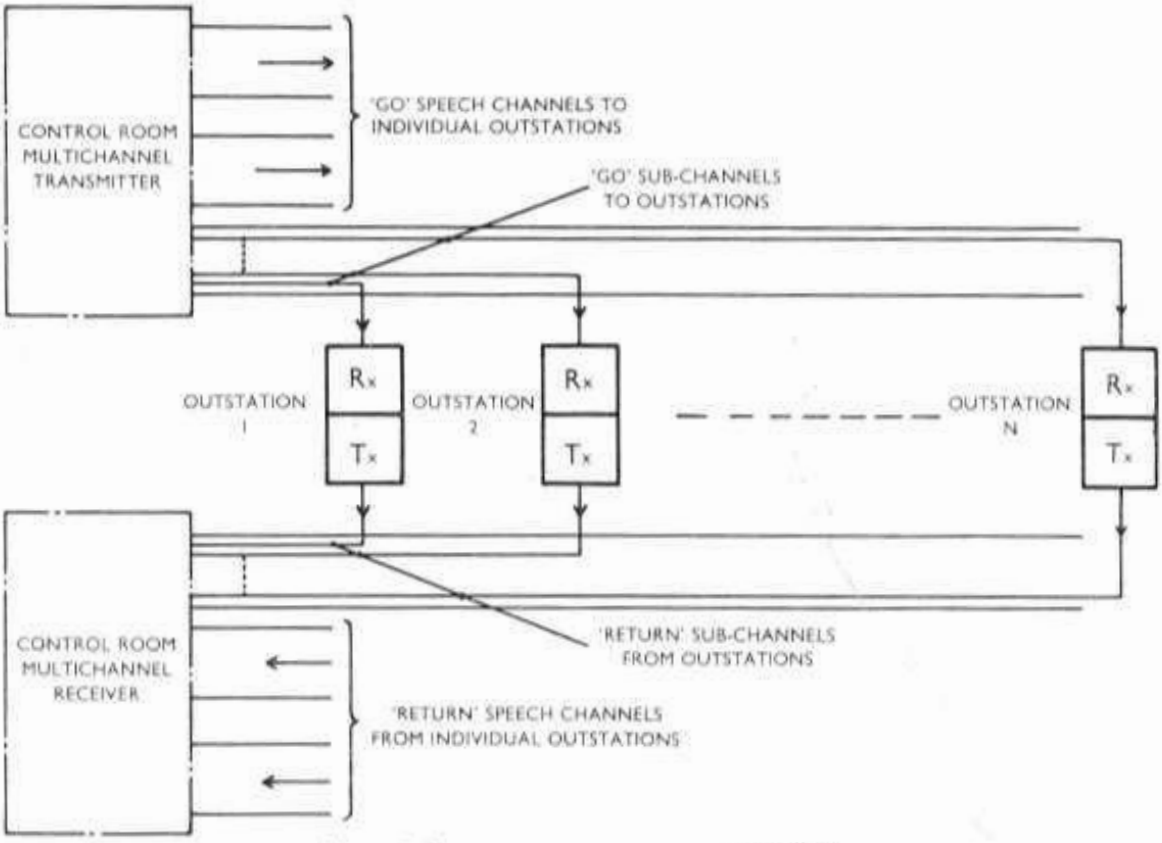


Fig.4. In-line arrangement of N outstations

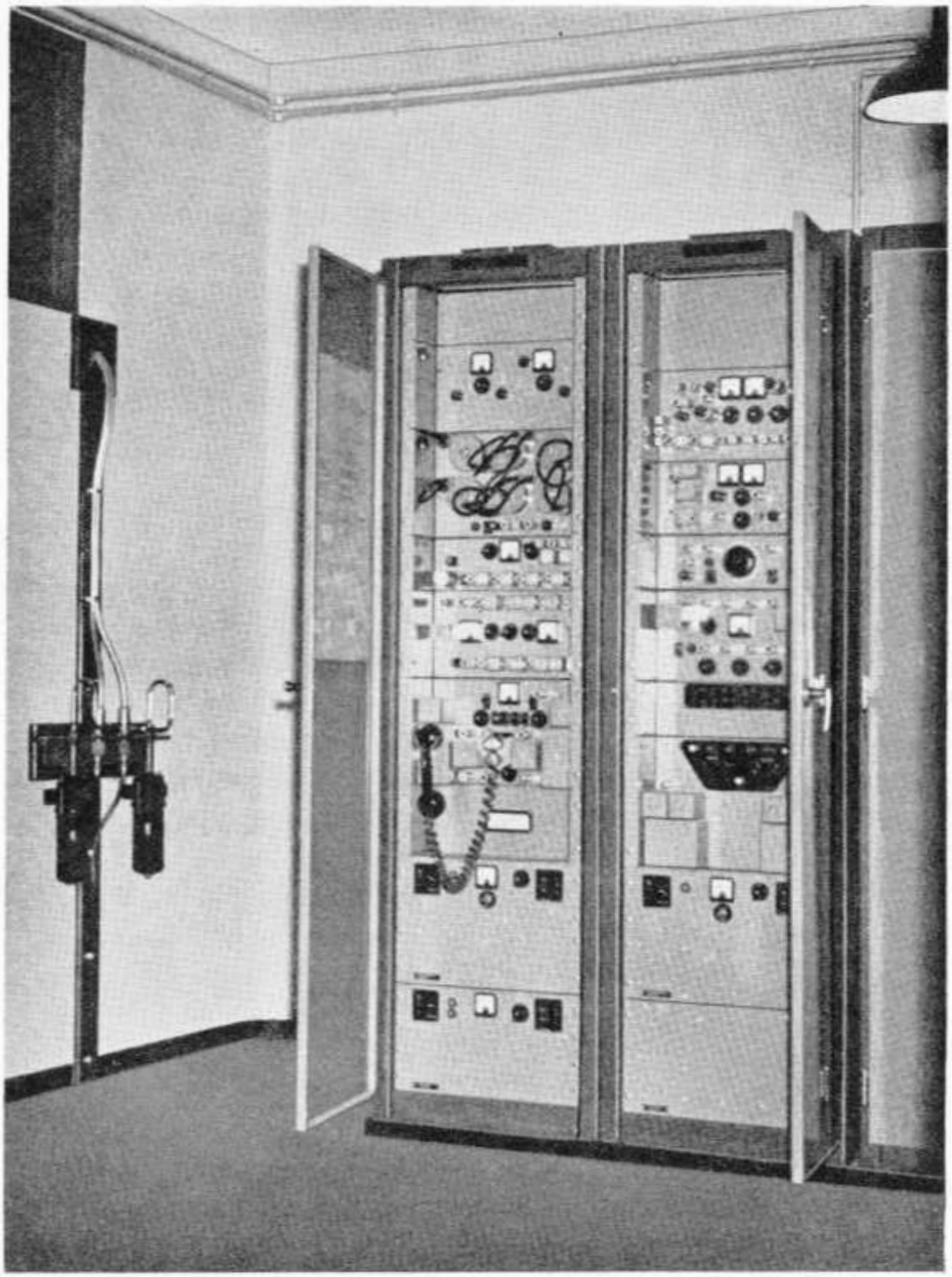


Fig.5. Typical multichannel radio equipment

In the first case an economical system can be provided by links carrying a single speech channel with a telegraph channel superimposed. A schematic diagram of such a system is shown in Fig.2 and typical single channel radio equipment in Fig.3. In its simplest form, the communication equipment at each outstation and at the control room consists only of a single transmitter, receiver and telegraph terminal unit. The scheme operates on a single pair of frequencies, 'go' and 'return', by providing for operation of each outstation in turn, in response to interrogation from the control room. By duplicating the communication equipment, and introducing a second pair of frequencies, a refinement of operation can be introduced, permitting interrogation of outstations to be maintained continuously while a remote control operation is in progress.

The second type of system is usually extended over a considerable distance along some kind of route and is ideally suited for multichannel point-to-point radio links. As before, one speech channel and one telegraph channel will be required per outstation. However, instead of combining speech and telegraph channels on an outstation basis, standard multichannel practice should be followed, combining all telegraph channels together by means of VF equipment in a single speech channel, and dropping them at individual outstations together with appropriate speech circuits. This is shown schematically in Fig.4 and typical multichannel radio equipment is shown in Fig.5. Individual outstations again report in response to interrogation, and to avoid interruption of routine calls when remote control is required, a second pair of VF channels per outstation may be needed.

4 TYPICAL TELEMETERING SYSTEM

4.1 PRINCIPLES OF OPERATION

An economical design for a telemetering system can be based on centralized control, in which case a single telemetering receiver at the control room can serve any number of outstations. (This solution implies that the control room communicates with each outstation only at its own request.) Interrogation calls are then sent periodically to each in turn, and each call is followed by a full report of the conditions there.

At the end of the report, the next outstation is interrogated, and so on. For the period between two successive interrogation calls, conditions remain unmonitored. However, as shown by the example in Section 2.6, these periods are normally short, and can be controlled by the design of the system.

The general arrangement of a system using centralized control is shown in Fig.6. The station calling codes are selected by the station distributor and passed to the transmitter at the central control room. The code is received by all receivers, but detected only at the required outstation. On detection of the call, the local transmitter is activated, transmitting the station identity code, which is checked at the central control station against the code originally transmitted to ensure correct outstation identification. The time multiplexing distributor then commences the scanning cycle of all points at the outstation. On each step the analogue signal from each transducer is converted into a digital telemetering character, as described in Section 2.5, prior to transmission. When received in the control room, the character is momentarily held in a character register before being routed to the appropriate display or logging position (selected by a system of 'gates' controlled jointly by the character and station distributors).

At the end of each scanning cycle, a station clearing signal is transmitted. On receipt of this signal a decoder at the control station steps the station distributor and selects the calling code of the next outstation, when the whole process is repeated.

An outstation has to report readings of a variety of parameters (rate of flow, temperature, number of revolutions, stroke rate, etc). Each parameter is detected by a transducer specially constructed for the purpose, the outputs of which depend to some extent on the function being measured. To obtain uniform signal levels, the output of each transducer feeds a converter (the analogue transmitter) to produce a standard AC or DC signal.

The conversion of standard signals into digital signals will take place usually on a time-sharing basis in an analogue-to-digital converter (ADC), which in Fig.6 forms part of the data handling circuits. Where the number of telemetered points at an outstation is small (say five or

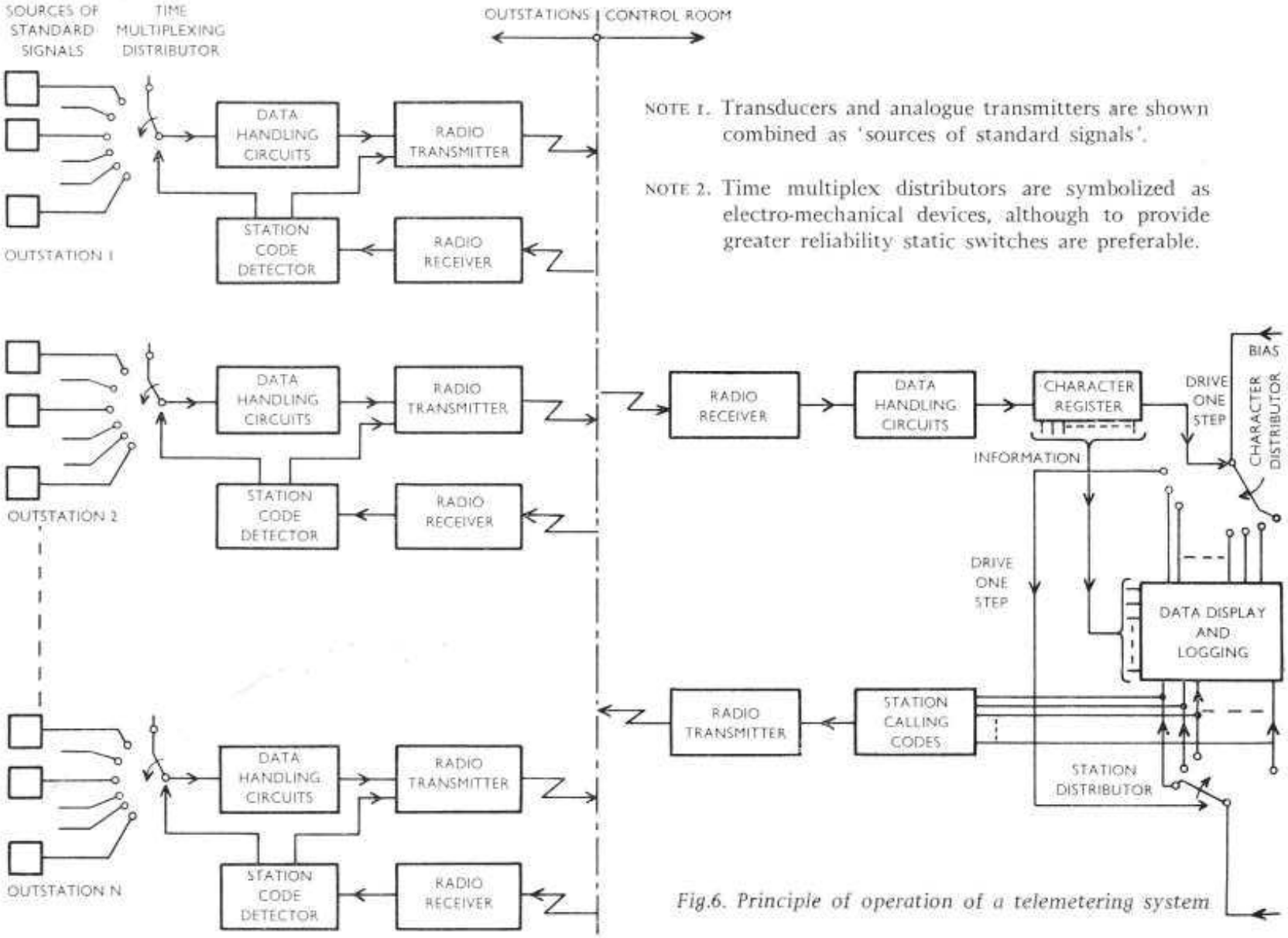


Fig.6. Principle of operation of a telemetering system

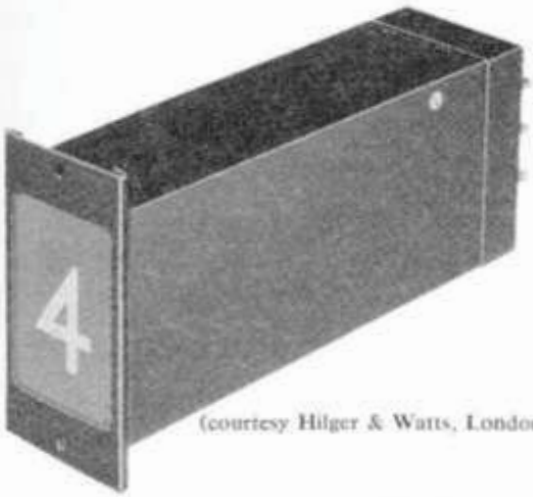
(courtesy Hilger & Watts, London)

Fig.7. Rotary digitizer

less), it is more economical to dispense with the ADC and to convert the analogue signals before multiplexing by means of individual rotary digitizers (see Fig.7) driven by the analogue transmitters. Their outputs can then be multiplexed and handled as before.

4.2 DISPLAY AND LOGGING FACILITIES

A convenient digital display can be arranged by means of 'in line' indicators (Fig.8), any number of which can be mounted together to provide readings of any required accuracy. For analogue displays, conventional recorders or dial instruments are an obvious choice and a typical recording unit is shown in Fig.9. The display units can be



(courtesy Hilger & Watts, London)

Fig.8. Projection type 'in line' indicator— the required numeral is projected on the screen

(courtesy Dewrance & Co Ltd)

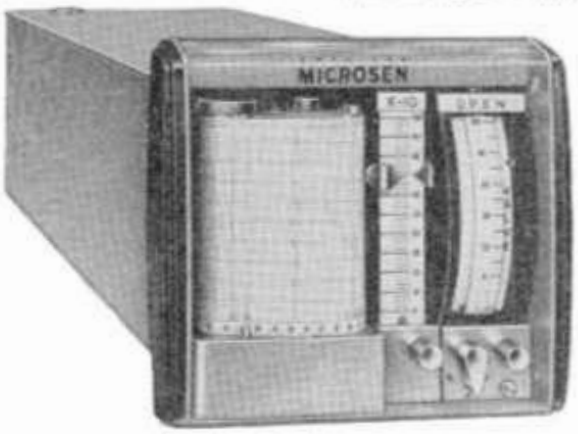


Fig.9. Typical recording unit

mounted either on the control desk or on the equipment cubicles or they can be associated with a mimic diagram of the system. This last arrangement is particularly useful in respect of displays of monitoring, supervisory or alarm signals.

To provide a permanent record of the operation of the system, a logging lineprinter or an electric typewriter should be attached to every control room equipment in order to record automatically any abnormality in system operation.

5 REMOTE CONTROL, PRINCIPLE OF OPERATION

Reliability in a telemetering system is important. It is even more important in the execution of control functions, and some form of revertive check must be used in the process of selecting a remote point for control purposes.

The most effective method is to use separate systems of keys for the selection, firstly of outstation, and then of the final control point, each selection being confirmed by revertive check before the next is attempted. A master key controls the operation once selection is complete.

Two types of remote control are generally required (in both cases the operation is limited to the change of state of a relay which actuates a local control). In the first case, the selected relay becomes energized or de-energized on receipt of a special code, while in the second, it becomes and stays energized for the duration of a continuous signal. The latter requires two types of signal, to determine, firstly, the direction of the control and, secondly, its initiation and duration. This is achieved by the use of separate tones, which operate relays associated with each direction of control while the signal is being received. The relays actuate the local servo-mechanism. The progress of the operation is observed on the display unit of the telemetering system connected to the affected parameter. Provision can be made in the distributors, either to monitor the affected parameter continuously, or to shorten the scanning cycle of the system if the nature of the control so requires.

6 CONCLUSION

The discussion has shown that telemetering and remote control of an installation over radio links is entirely practical providing that the

system is engineered to meet certain conditions. The design of the telemetering and remote control equipment should be based on the digital principle, using binary notation for ease of detection and binary decimal coding for simplicity of the coding and decoding circuits. Time multiplexing of the telemetered information will give maximum economy of communication channels, and the start-stop principle of transmission room must be of suitably high quality, so that undetected transmission will minimize the quantity of equipment at the control centre. Lastly, the radio links connecting the individual outstations and the control room must be of suitably high quality, so that undetected transmission errors remain within the limits determined by the required reliability of the system.

Acknowledgment

The author is indebted to engineers of the Control and Data Processing Division of the English Electric Company Limited, Kidsgrove, for fruitful discussions on the subject and for help in obtaining some of the photographs.

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Having obtained a British Council postgraduate scholarship, he came to England in 1948 to study British Railway signalling practice. In 1950 he joined the General Electric Company at Coventry as a circuit development engineer, primarily concerned with development of filters. He continued to work on filters after joining the Receiver Group of the Marconi Company in 1954. After transferring to the Communications Division he became primarily concerned with the application of communication systems in automation and process control and with planning of data transmission systems.

A Tropospheric Scatter Link over a 200 mile Path

G. L. GRISDALE, B.Sc, Ph.D, and
D. A. PAYNTER, A.M.I.E.E, A.M.Brit.I.R.E

The literature on tropospheric scatter propagation is extensive, but little has been published on operational systems. This article reviews the performance of an operational link, carrying various types of traffic over a period of a year.

1 INTRODUCTION

A CONSIDERABLE AMOUNT of information has been published, [1, 2] about radio propagation over the horizon using forward scatter from the troposphere; little has appeared on the application of the phenomenon for practical communication purposes.

The previous work indicates that, given sufficient transmitter power and aerials of the required gain, a link capable of carrying traffic with a high degree of reliability is a practical proposition. To prove this in practice, and permit critical evaluation under practical conditions, a full-scale system was set up. The main objects of this experimental link were the demonstration of multi-channel telephony and telegraphy, the development of equipment for production, and the confirmation of data for the planning of operational systems. The link operated in one direction only but was capable of carrying 24 telephone channels with spaced-aerial diversity at the receiving station. Several methods of modulation were investigated and finally a television picture was transmitted over the link.

The only practical source of high-power at UHF is the klystron power amplifier. As tubes were available capable of producing 10kW at frequencies below 1000Mc/s, it was decided to operate the link in this band. A frequency of 858Mc/s was allocated.

The link was operated from March 1958 to May 1959 and the results confirmed that such a system would give reliable communication over terrain where the provision of repeaters was impracticable.

2 SITES FOR TERMINAL STATIONS

The choice of sites for tropospheric scatter terminals must be made with care, as the path attenuation increases rapidly as the angle of elevation of the aerial beam is increased. Conversely, a reduction of path attenuation is obtained if the horizon allows the beam to be depressed below the horizontal, as is the case with an aerial on high ground overlooking the sea.

The acquisition of suitable sites in England presented some difficulty, as sites separated by the chosen distance with no obstructing foreground and with adequate power supply are few in number and were not necessarily available. In the circumstances in which tropospheric scatter links are likely to be used, however, for example over sea paths and in sparsely populated areas of the world, these difficulties are not likely to be as great.

For this experimental demonstration link, most of the active work would occur at the receiving end, so this should be located near to the development laboratory; a site was acquired on a disused racecourse at Galleywood, near Chelmsford, at a height of 250 feet above sea level. At this site, a horizontal beam would be negligibly obstructed by higher ground in any direction between SW and N.

The transmitter site was near the broadcasting station at Start Point, 206 miles (330km) from Galleywood, and 400 feet above sea level. The first 55 miles of the path was across the sea at Lyme Bay, with negligible obstruction from the hills at the other side of the bay, so that the transmitter beam could be depressed by about 0·4°. The route and profile are shown in Figs.1 and 2, from which it can be seen that the route passes over London, Farnborough and near London Airport. Because the elevation angles are not the same, the common volume enclosed by the aerial beams is east of the mid-point, at a height of 5000 to 10000 feet.

3 THE EXPERIMENTAL SYSTEM

3.1 AERIALS

For this one-way link, one aerial was required for transmission and two spaced aerials for diversity reception. Parabolic dish reflectors 30 feet in diameter with a focal length of 10 feet were employed. The dishes

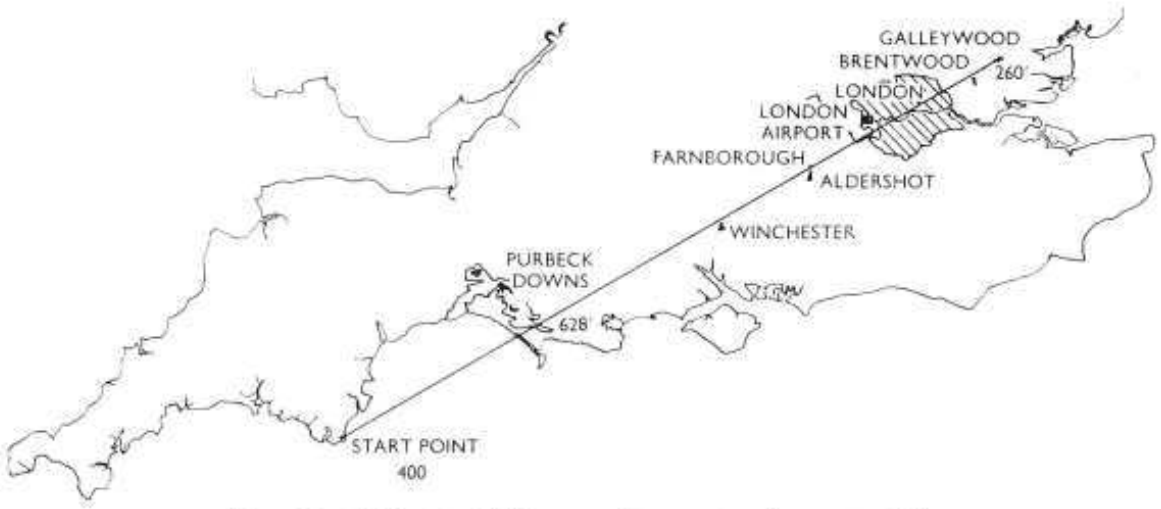


Fig.1. Start Point to Galleywood tropospheric scatter link

were illuminated by a horn, centrally mounted in front of the dish, and fed by a 3 ¼ inch concentric feeder for the transmitter and by 1 ⅝ inch helical membrane coaxial feeder for the receivers. The dishes were constructed of solid sheet steel and gave a calculated and measured plane-wave gain of 36dB at 1000Mc/s. The dish and feedhorn could be moved, both in azimuth and elevation, by $\pm 2^\circ$ for the purpose of alignment in the optimum direction. The Start Point aerial is shown in Fig.3. Final alignment of the aerial to give optimum signal can be a problem,

Fig.2. Profile—Start Point to Galleywood

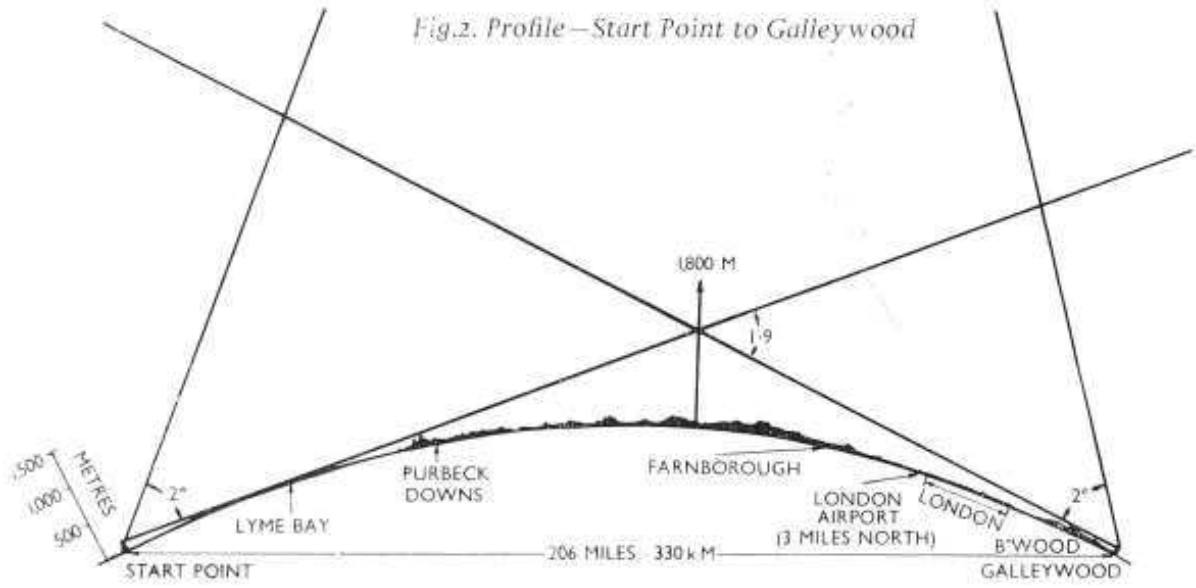


Fig.3. Start Point aerial and transmitter building

since the scatter signal strength is continually changing. It is helpful to use a wide beam receiving aerial when the transmitter dish is aligned; the narrow beam receiving aerial can then be correctly adjusted. It is convenient to use the feedhorn for this widebeam aerial, turning it round to face the transmitter instead of pointing to the dish.

Both horizontal and vertical polarization could be employed as it was intended to use the isolation between the vertical and horizontal probes in the feedhorn as a part of the receiver protection when operating a receiver from the same aerial as a transmitter. Thus in one direction, the transmission could be vertically polarized, and in the other horizontally polarized. The transmitter frequency is usually spaced from the receiver frequency by at least 50Mc/s; with a frequency spacing of 50Mc/s, the selectivity of the receiver is not sufficient to attenuate the local transmission to a level at which damage or cross-modulation will not occur in the receiver. From theoretical considerations it was decided

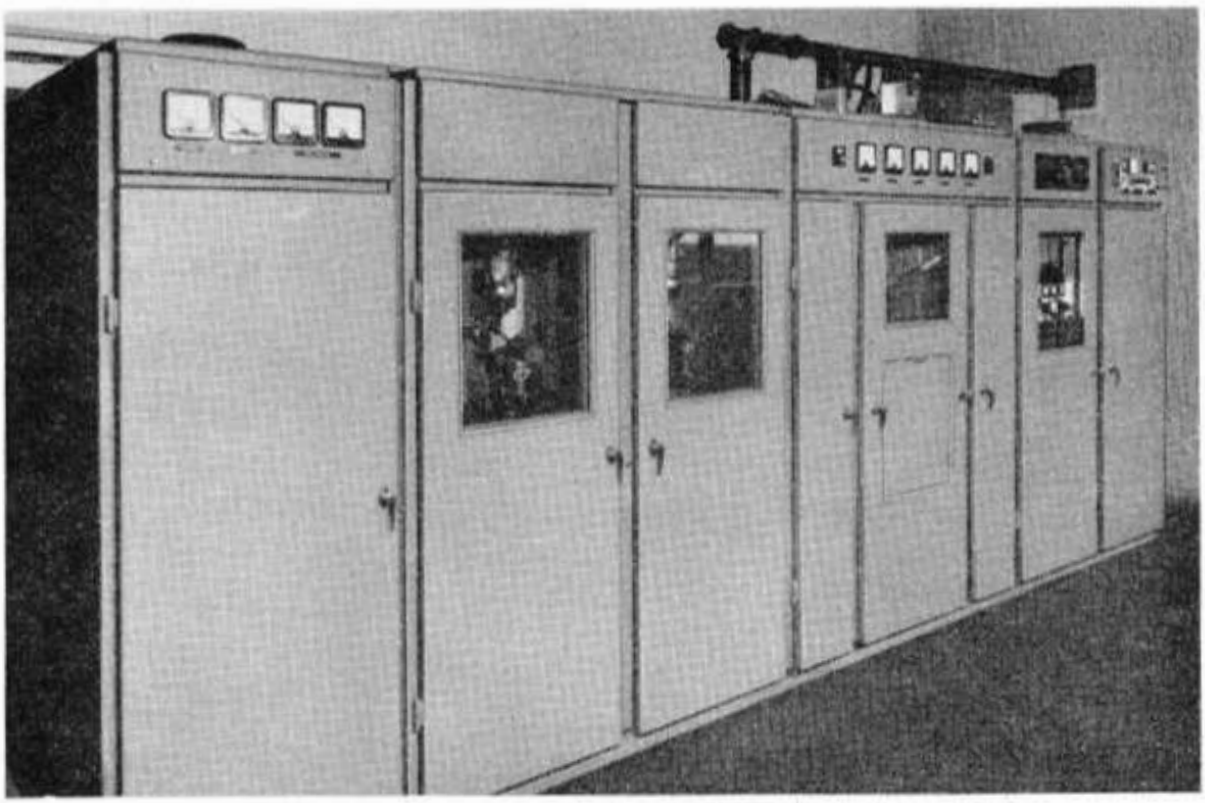


Fig.4. 10kW tropospheric scatter transmitter

to introduce at least 100dB attenuation in the receiver feeder at the transmitted frequency. This attenuation was obtained in two ways:

(a) Isolation in the horn due to the use of cross polarization

(b) Coaxial-line bandpass filters in the receiver feeder.

The receiver protection against the transmitter frequency consisted of 40dB polarization protection and signal filter rejection of 60dB. With a 10kW transmitter this would give −60dBW at the receiver input which, coupled with the protection provided by the receiver itself, is adequate.

3.2 TRANSMITTER

The transmitter which was sited at Start Point is shown in Fig.4. It uses a four-cavity power klystron capable of delivering a power of 10kW at frequencies of 600−970 Mc/s. The excitation required for full output varies with the cavity adjustment for different bandwidths, but does not exceed 1 W. For the Start Point experiment, the transmitter had a half-power bandwidth of 6 Mc/s. The 10kW output corresponded to the limit of the linear input/output characteristic of the amplifier. Although frequency-modulation does not require such linearity, it was necessary for the single-sideband modulation and the two carrier tests.

For radiating frequency-modulated multi-channel telephony, two methods of producing the excitation power at final radiated frequency are available. Either the output of a suitable frequency modulator may be multiplied up to the required frequency, or the FM signal may be generated at a suitable intermediate frequency, and translated to final frequency in a mixer circuit. Modulation equipment using both methods was provided for the transmitter. One drive circuit (shown in Fig.5) employed a frequency modulator operating at a frequency in the region of 2 Mc/s, capable of accepting modulation up to 108 kc/s, followed by a series of multipliers, finally producing 858 Mc/s which could be fed to the klystron. The alternative drive unit (Fig.6) utilized a crystal-controlled local oscillator of 823 Mc/s and a balanced mixer, a 35 Mc/s modulated signal to the balanced mixer produced 858 Mc/s, which was then amplified by linear power amplifiers to provide the klystron excitation.

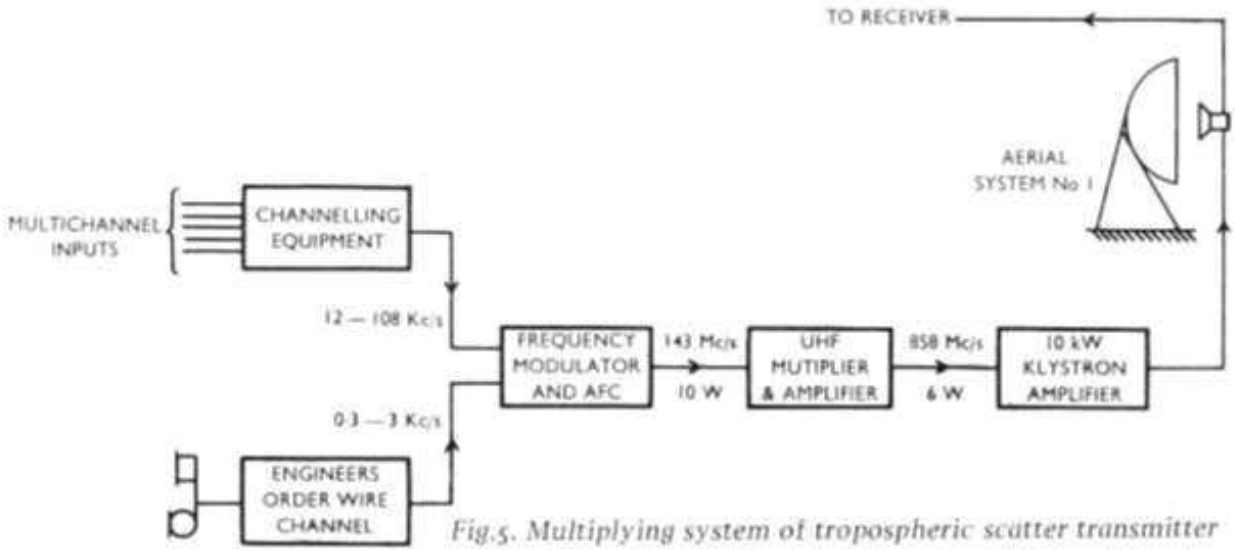
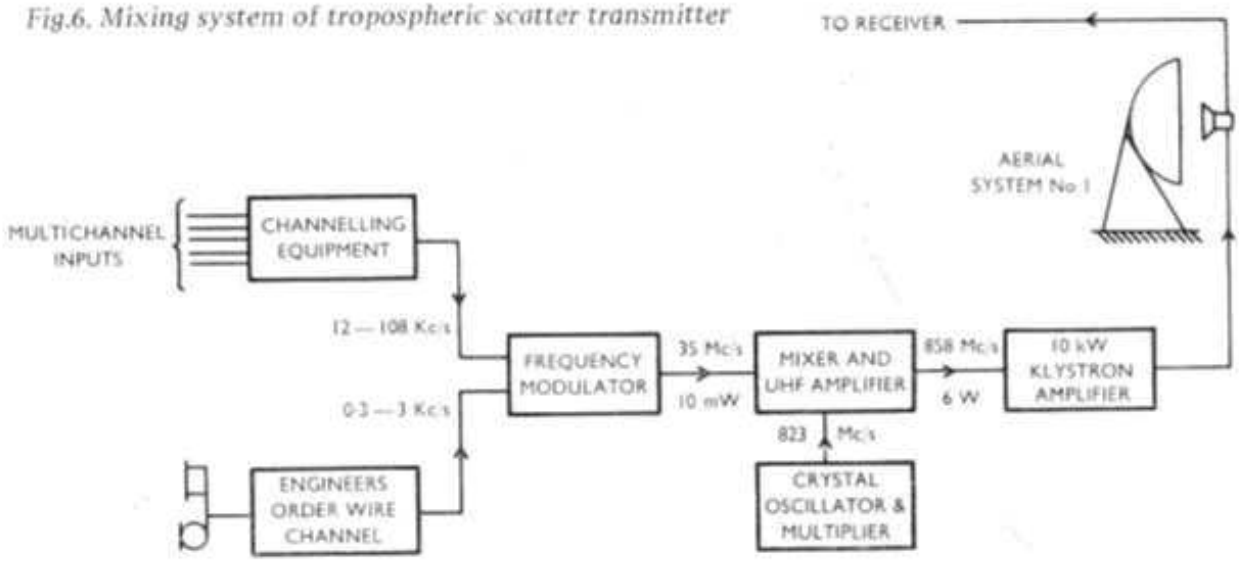


Fig.5. Multiplying system of tropospheric scatter transmitter

The drive using multiplication was used only for 24-channel telephony, but the wideband frequency changer system could be used for experimental purposes with any of the following modulations:

(a) 24-channel telephony with frequency modulation
(b) Frequency modulation up to 4 Mc/s bandwidth
(c) Pulse amplitude-modulation for propagation tests
(d) Crystal controlled drive giving high-stability carriers
(e) Single-sideband modulation with 24-channel telephony.

Fig.6. Mixing system of tropospheric scatter transmitter



Although the system was basically designed for 24 telephone channels, only two live channels were provided for demonstration purposes, one in the band 16-20kc/s and the other from 88-92kc/s. To simulate full traffic loading, a white-noise generator was provided, with appropriate filtering, to fill in the vacant channels. The telephone channels could be modulated from a telephone handset, high quality microphone, records, broadcasting or frequency-shift telegraph signals, as well as the usual tone sources for measurement purposes. Towards the end of the experiment, a television monoscope camera and sync-generator were installed to feed the wide band FM modulator in order to transmit a test card over the link.

3.3 RECEIVERS

The arrangement of receiving equipment at Galleywood is shown in Fig.7. The two receivers were each fed by a separate dish to give space diversity. Operating on 858Mc/s, they comprised rat-race mixers, head IF amplifier, main IF amplifier, limiter and Round-Travis discriminator. For 24-channel working the main IF bandwidth was 800kc/s, centred on 35Mc/s. Automatic gain control was included to accommodate the large range of signal inputs.

The noise factor of the receiver is of paramount importance in a system in which high transmitter powers are used to achieve satisfactory performance. In the UHF frequency range, consideration must be given to the relative merits of valve amplifiers, low-noise mixers and travelling-wave tubes. In the experimental receivers a rat-race type of mixer using two crystals was used, largely because a suitable well-tried design was available for radar applications at a slightly higher frequency than that allocated; the noise factor of this mixer was 8dB.

For a production receiver (shown in Fig.8), a grounded-grid amplifier was developed, using a disc-sealed triode with concentric line tuning. The noise factor of this amplifier was 6·5 to 8dB over the frequency range. The input filter contributed a further loss of 1 to 1·5dB. There were several reasons for adding the valve amplifier; it could be tuned to the band 610 to 970Mc/s without modification, whereas a typical design of rat-race mixer covered only 50Mc/s; the input filters require a match

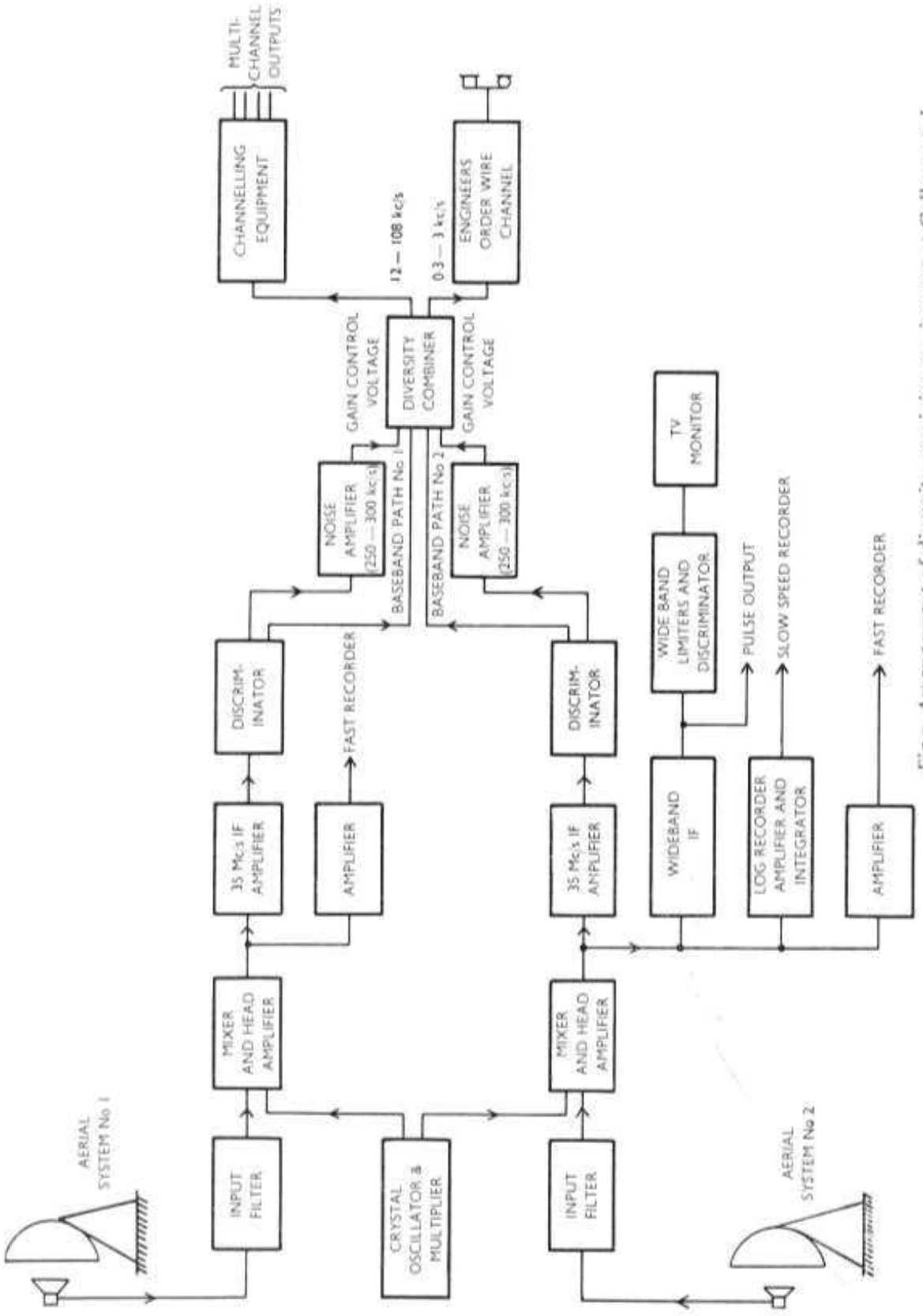


Fig.7. Arrangement of diversity receiving equipment at Galleywood

of better than 1·2 VSWR over the receiver passband, which can be obtained only at the centre of the rat-race frequency range; also, difficulty can be encountered in a crystal mixer because the impedance of the input circuit at the intermediate frequency is coupled to the output through the crystals, causing large variation of performance. (The last two points can also cause great difficulties with parametric amplifiers, where the noise factor is very dependent on the input matching conditions.)

The demodulated baseband outputs of the two receivers were combined as a function of their instantaneous signal-to-noise ratio to give the optimum signal-to-noise ratio at the combined output.[3] This was achieved by amplifying a band situated above the highest modulation frequency, and rectifying the noise contained therein to produce a DC bias which is fed to the grid of a cathode follower in the demodulated output of the receiver. The two cathode followers of the two receivers

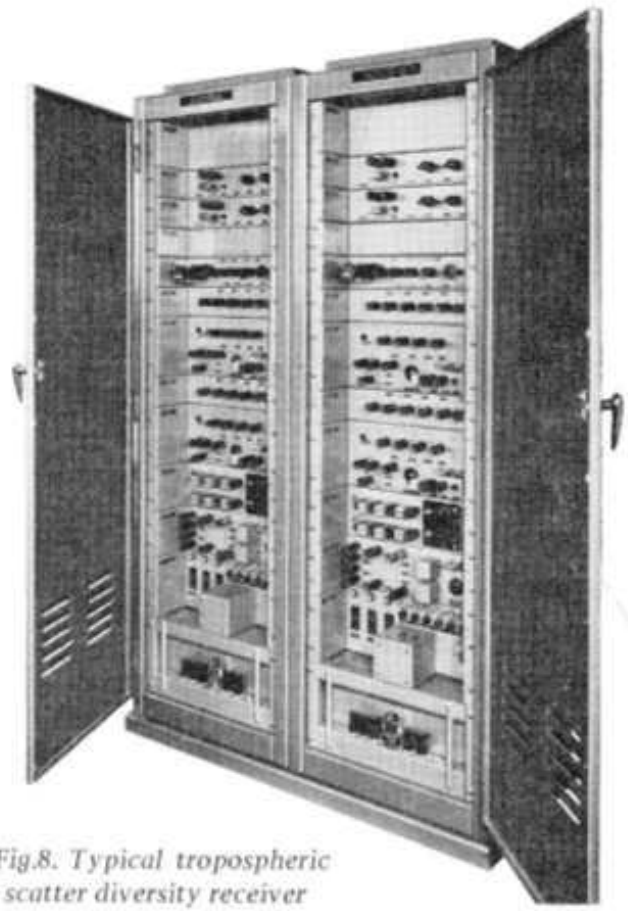


Fig.8. Typical tropospheric scatter diversity receiver

have a common cathode load, and the signal appearing across this load is fed to the line amplifier. Thus, at any instant, the receiver with the better signal-to-noise ratio made the greater contribution to the combined output. This simple form of combiner was found to give a diversity performance very close to the optimum, provided the signal and control voltages were selected with care.

The 12-108kc/s output from the line amplifier was fed to the channelling equipment which translated the two channels 16-20kc/s and 88-92 kc/s, used for the demonstration link, down to audio frequency.

The output of the channelling equipment could be connected to telephone handsets, monitor loudspeaker, tape recorder or, via a tone-telegraph bridge, to a teleprinter.

For receiving television pictures or pulse transmissions, a 6Mc/s IF amplifier and FM demodulator could be connected to the output of the head IF amplifier. Spaced-aerial diversity was not used during the television tests.

Facilities were provided for continuously recording the level of the received signal. This was achieved by the provision of an additional amplifying chain connected to the output of the head IF amplifier of each of the receivers. Two recorders were used, one for continuously recording the signal level throughout the day and the other, a fast-acting two-channel recorder, for intermittent recordings of the fading characteristics of the received signal. A logarithmic amplifier with a 20-second time constant (to eliminate fast fading effects) was incorporated in the chain feeding the slow recorder. The recording amplifiers of the two receivers could also feed a rack of counting equipment capable of providing a statistical analysis of the fading signal, and the correlation existing between two received signals.[4]

4 THE EXPERIMENTAL PROGRAMME

The link commenced operation on the 11th March, 1958, and, except for two gaps of a month, continued until 29th May, 1959. It was considered desirable that the transmitter should be attended, and this was the limiting factor in deciding operating hours of the system. The receiving terminal could operate unattended, but in general it was

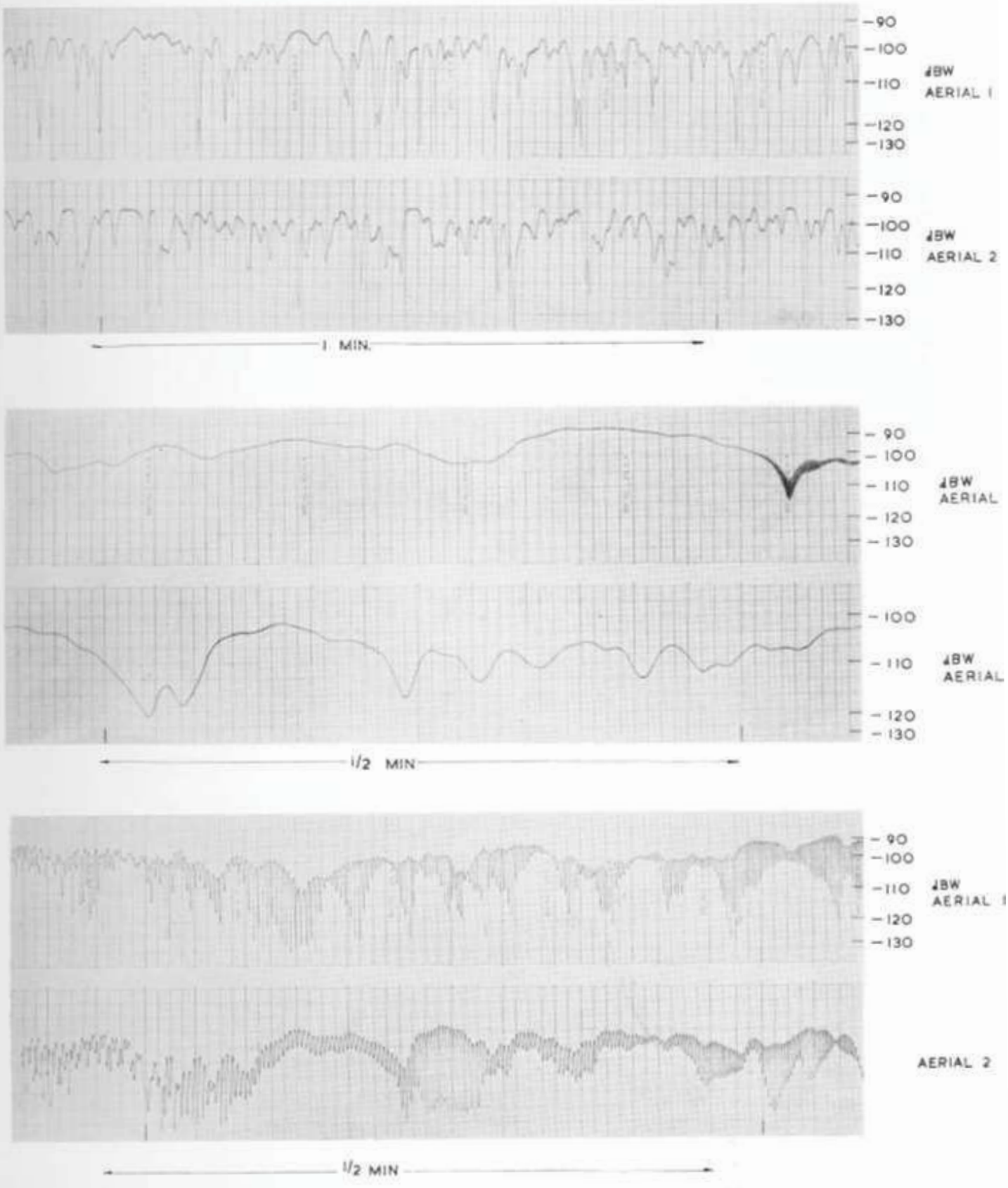
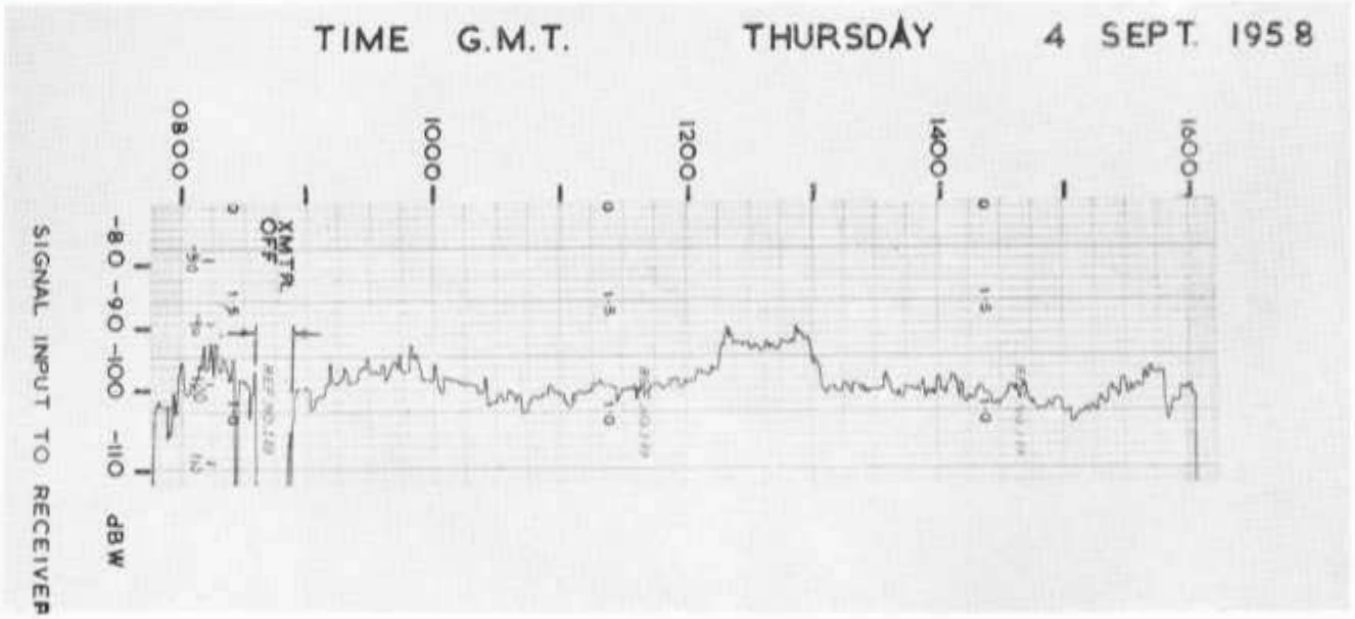
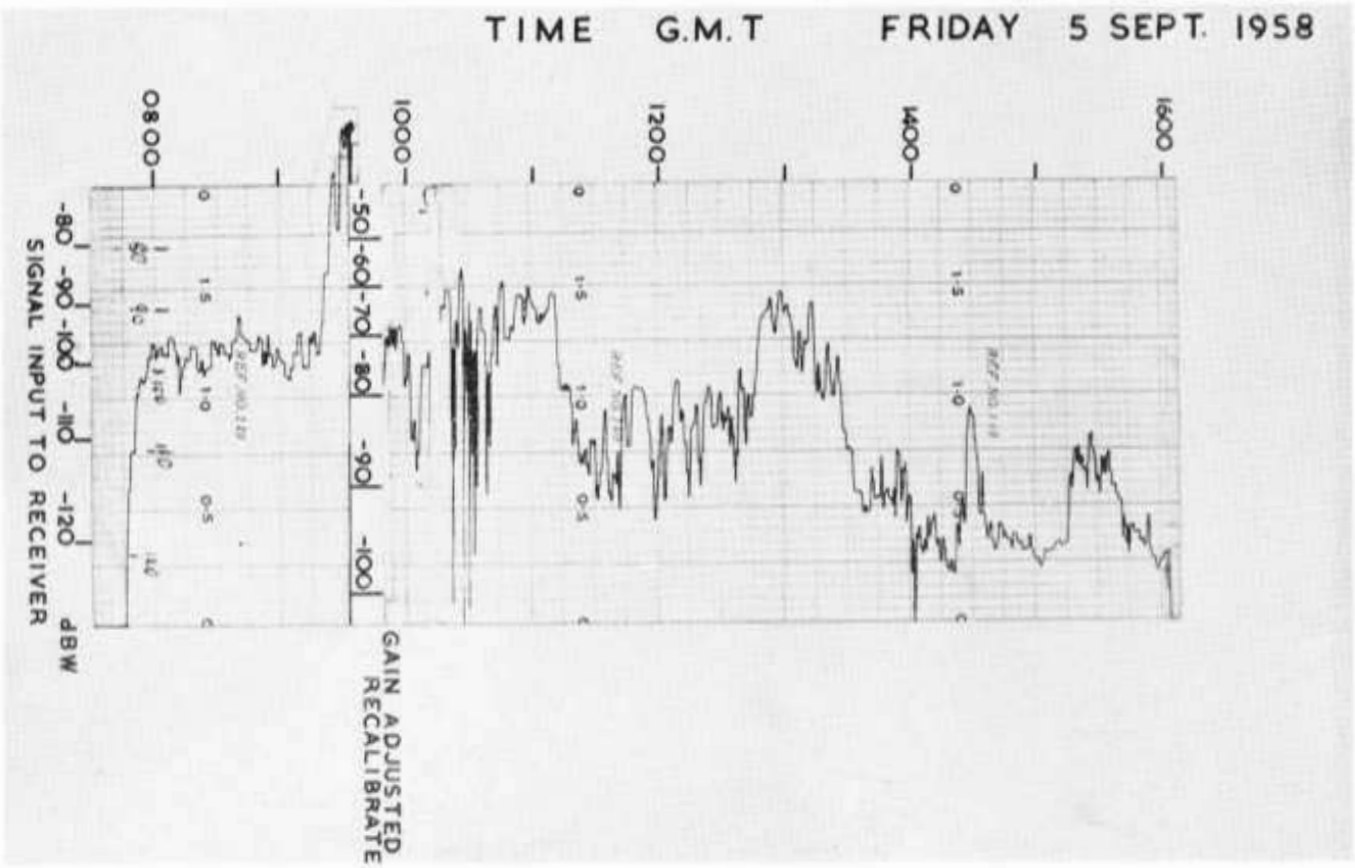
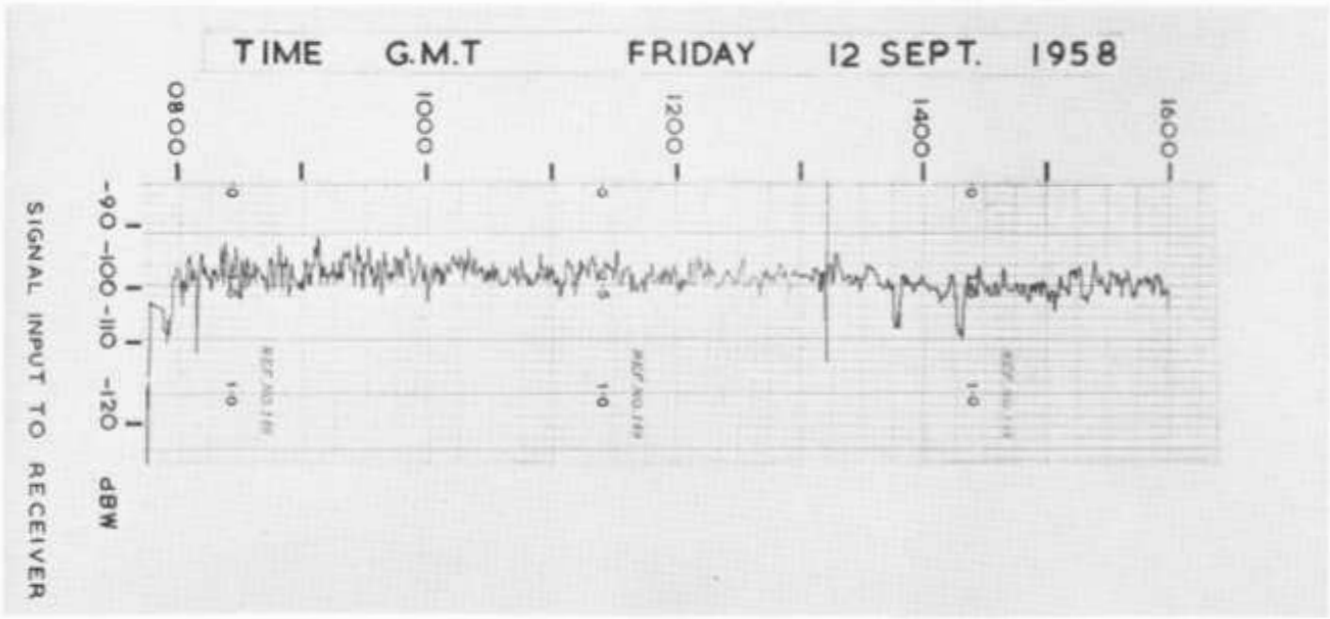


Fig.11. Received signal strengths, taken on fast recorders, showing fading patterns


TIME G.M.T. THURSDAY 4 SEPT. 1958
0800
1000
1200
1400
1600
XMTR OFF
-80 -90 -100 -110 dBW
SIGNAL INPUT TO RECEIVER


TIME G.M.T FRIDAY 5 SEPT. 1958
0800
1000
1200
1400
1600
-50 -60 -70 -80 -90 -100
GAIN ADJUSTED RECALIBRATE
-80 -90 -100 -110 -120 dBW
SIGNAL INPUT TO RECEIVER



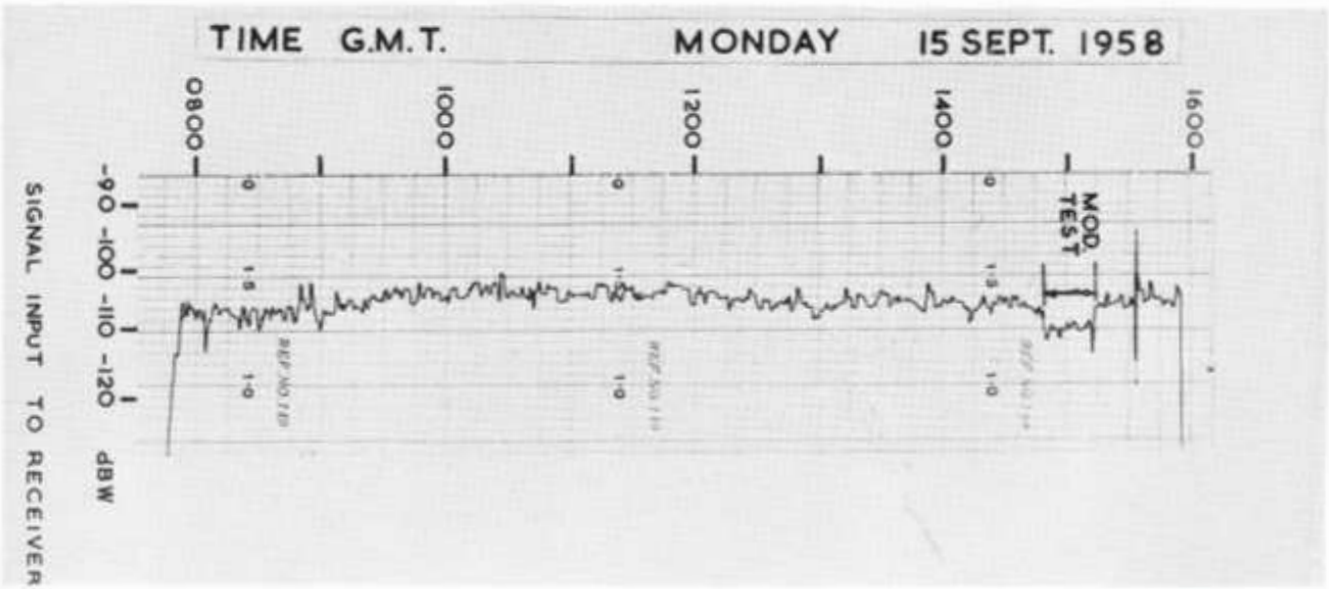
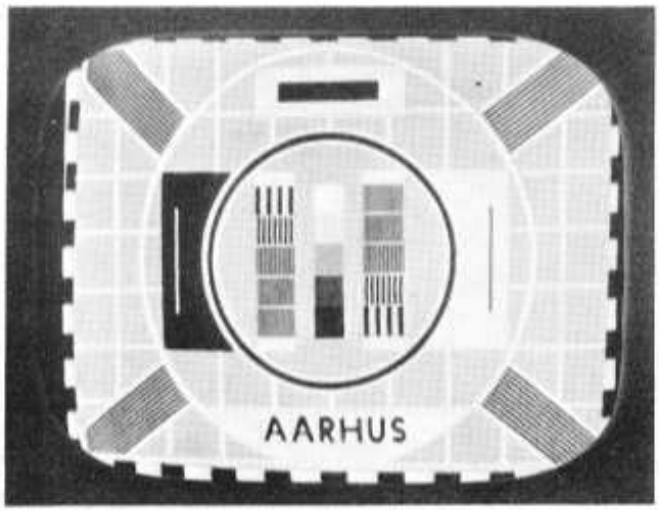
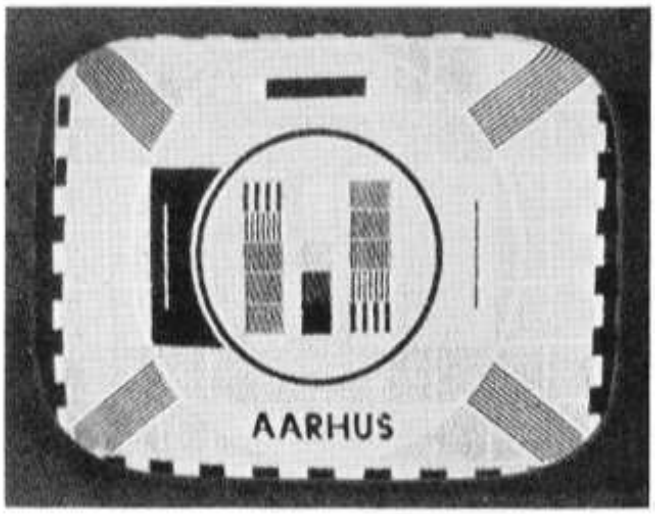


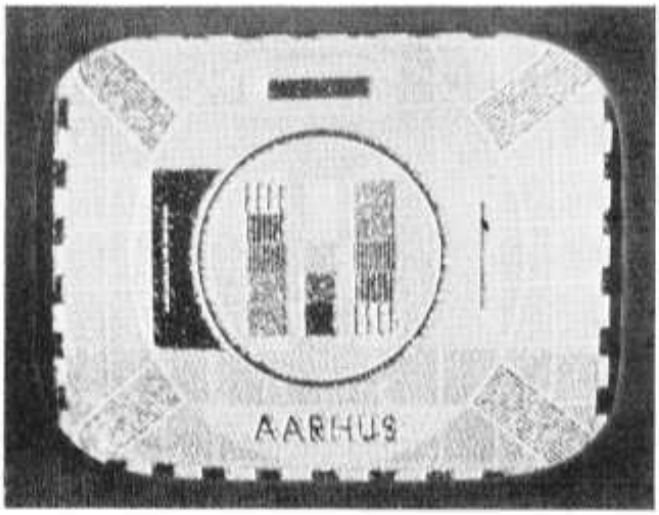
Fig.9. Typical mean field-strength records



(a) Signal at good level

(b) Fading signal – poor SN





(c) Signal at bottom of fade, echoes present

Fig.14. Television Monoscope picture over 200 mile tropospheric scatter link

necessary to staff the station in order that tests could be made and demonstrations performed. Operation was generally for eight hours a day, five days a week. To gain experience of propagation at various times of day and night, however, the hours of operation were varied over three shifts of eight hours; a complete 24-hour cycle being accomplished in three weeks. A 36-hour continuous run was also made.

4.1 PATH ATTENUATION

It was anticipated that the highest path loss would occur during the winter months. This was not confirmed over the period that the link was operated, as unusually high signals were recorded during the winter 1958/1959. This was possibly due to the high humidity during that period (on one day the path loss actually corresponded to line-of-sight attenuation).

In order to record continuously the level of signal received, a pen recorder operating at 1 inch per hour was fed with mean signal level information. Fig.9 shows some typical records obtained from the slow recorder with a 20-second time constant. The recording made on the 5th September, 1958, is unusual, because at approximately 09.30 hours the signal increased to such an extent that it exceeded the range of the recorder, necessitating a reduction in the gain of the amplifier. The sudden, large changes of signal strength experienced on that occasion were unusually high, and coincided with the occurrence that evening of one of the worst storms ever experienced in England. These violent fluctuations were not experienced at any other time during the period of the tests. From the slow recordings obtained during the operation of the link, the monthly median levels have been computed and are shown in Fig.10. These generally agree with the results published by other workers.

An additional amplifying and frequency changing channel for each receiver fed a two-channel high-speed pen recorder. This recorder could operate at a speed of up to 24 inch/min. and would respond to frequencies up to 50c/s. It was used to give an accurate record of the rapidly fluctuating signal for periods of several minutes; Fig.11 shows examples of these recordings. The characteristic beat caused by an aircraft flying

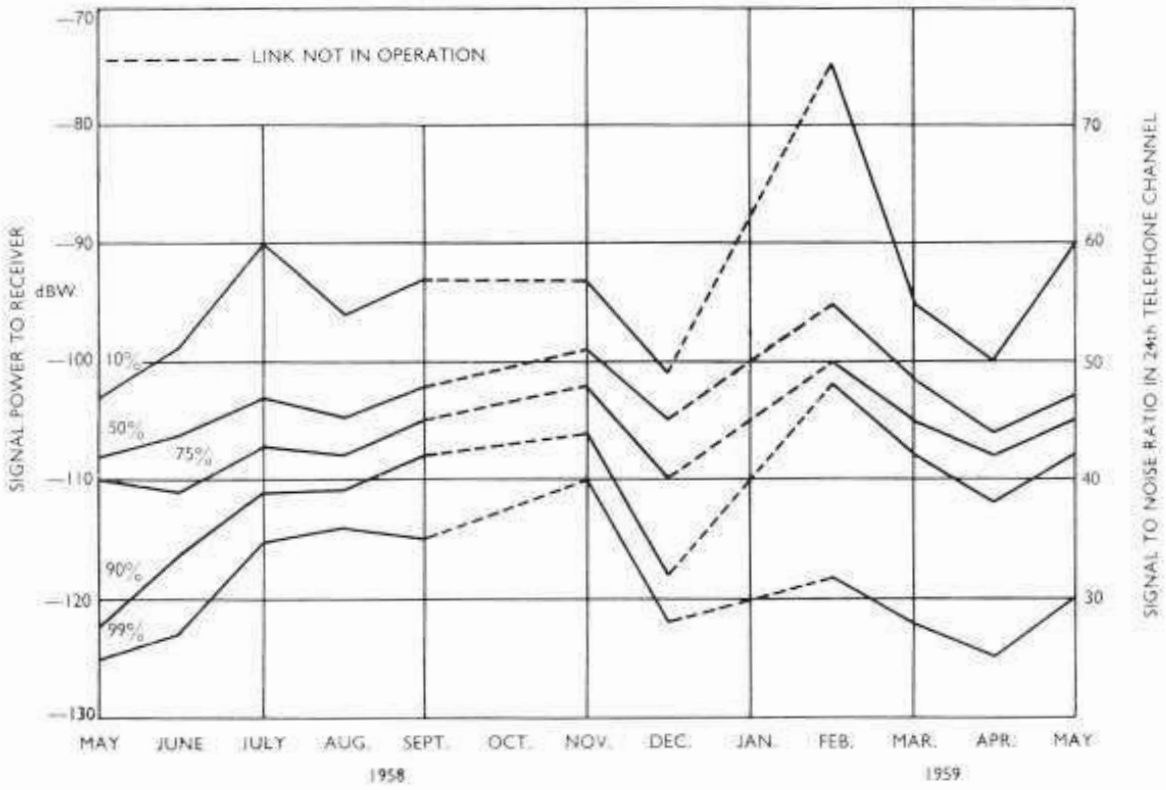


Fig.10. Monthly median levels of the Start Point to Galleywood link

in the common volume of the aerial beams can be seen in the lower recording. Because this intersection of beams was located in a region of high aircraft density, this type of regular fading occurred frequently. It was reduced by diversity working, and did not seriously affect telephone communication.

4.2 TELEPHONE CIRCUIT PERFORMANCE

The speech quality received over the channels was consistently good, providing for most of the operating time a signal-to-noise ratio adequate for commercial telephone service, although not conforming to the high standards demanded by C.C.I.R for microwave links.[5] Fast fading caused 'drop-out' of signal below the threshold level of the receivers, but this was of such short duration that it manifested itself as a 'click'.

Subjectively this was of little importance on telephony and in any case was greatly reduced by diversity working. The signal-to-noise ratio

in the 24th channel is shown in Fig.10. It is 17dB inferior to that of the 1st channel.

Comparative magnetic tape recordings were made between a telephone conversation over the normal trunk line to Start Point and that received via the tropospheric scatter circuit (an HF SSB system providing the return path). Identical telephone handsets were used in each case with an external magnetic pick-up coil. The tropospheric scatter circuit compared favourably with the land-line, the latter providing a signal considerably down in level and with inferior signal-to-noise ratio.

4.3 USE OF COMPANDORS

It is desirable on an FM radio link that a speaker should produce the maximum deviation that the system allows in order to provide the highest signal-to-noise ratio. The compandor attempts to do this by compressing the dynamic range of speech on the audio channel in order to provide a higher average level of modulation, and expanding it at the receiving terminal to restore the original dynamic range.

Compandors were installed at each terminal of the tropospheric scatter link so that they could be inserted into either channel as desired. A number of comparative tape recordings of speech and music were made with and without compandors on the link, under a variety of conditions of signal strength. The tests were made with full and reduced transmitter power, with and without diversity, in good and poor propagation conditions. A poor telephone line was simulated by reducing the energizing voltage on the telephone handset. The compandors were also tested with SSB modulation under poor propagation conditions extending over a considerable time.

It is difficult to come to a definite conclusion as to the results of the tests, as they relied on the subjective impression of the observers who listened to the comparative recordings. However, certain conclusions can be drawn. An improvement in signal-to-noise ratio was, in general, apparent from the use of compandors but in other respects the impression gained was unfavourable. The time constants of the expander and compressor were such as to operate within syllables of speech, and this tended to give a peculiarly clipped effect to the received speech. An

additional complication was introduced by the diversity combiner, which tended to suppress noise bursts and introduced a variable gain in the channel which affected the operation of the expander. It is not possible, therefore, as a result of these tests, to arrive at an agreed opinion that compandors provide improved intelligibility. It would appear desirable, however, that some means of maintaining an adequate level of modulation on weak telephone calls should be employed at the transmitter to enable the best signal-to-noise ratio to be obtained. A constant volume amplifier in each channel of the transmit path having a comparatively long time constant would possibly provide the necessary improvement. The consequent lack of dynamic range at the receiver is unlikely to affect intelligibility seriously.

4.4 TELEPRINTER OPERATION

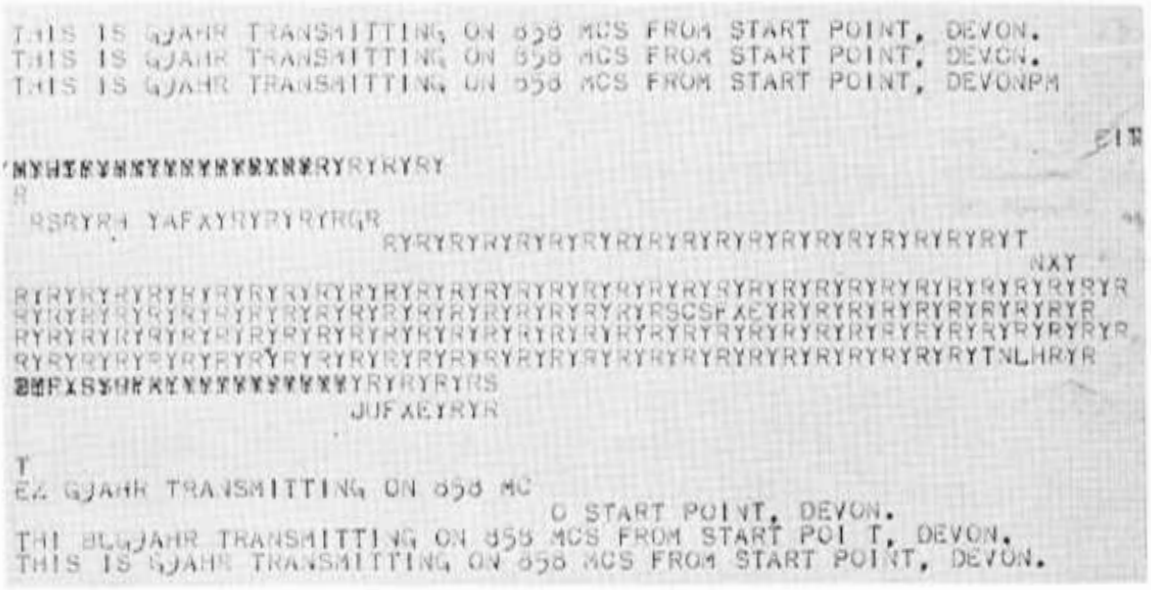
The short drop-outs which occur due to fading with tropospheric scatter propagation are a factor which jeopardize the operation of teleprinters on such circuits. Accordingly, trials were arranged using a teleprinter operating from frequency-shift VF telegraph equipment. Tests were conducted at various levels of tone into a channel and with reduced transmitter power to simulate condition of high path loss. It was found possible to obtain satisfactory copy with a tone level of −18dBm into the two-wire point of the channelling equipment. (At −18dBm each telephone channel would accommodate seven telegraph channels.) Diversity working was, however, essential as the short bursts of noise occurring during fading would otherwise cause errors. Convincing demonstrations were made by operating the teleprinter with and without diversity (Fig.12). The improvement in transmission is very obvious for telegraph transmission, whereas on telephony the subjective improvement is more difficult to assess.

4.5 COMPARISON OF FREQUENCY MODULATION AND SINGLE SIDEBAND AMPLITUDE MODULATION

The telephone channelling equipment used on radio links usually translates the audio speech bands to a series of single sideband signals at higher frequencies. This spectrum is then applied to a frequency modulator for transmission over the link.

An alternative method of transmission is to translate the spectrum appearing at the output of the channelling equipment to the required radiated frequency.

For a 24-channel system using FM, the signal-to-noise ratio is 17 dB better for channel 1 than for channel 24. Using SSB, all channels have the same signal-to-noise ratio, and this is 2 dB worse than for FM on channel 24. (These calculations assume that the received signal level is above the threshold of the FM receiver; as the signal drops below the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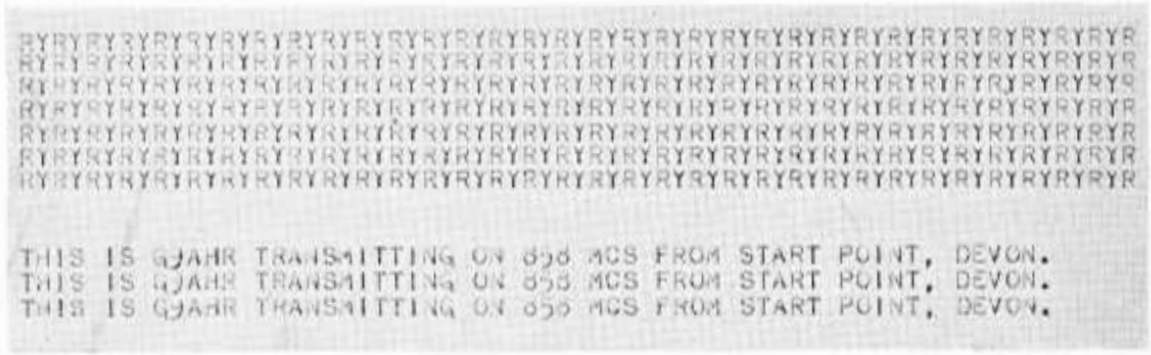
(a) Without diversity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(b) With diversity

Fig. 12. A comparison between diversity and single receiver working with teleprinter. Power 1 kW. Received level −125 dBW

threshold level, the signal-to-noise ratio will deteriorate at a greater rate in the FM case than with SSB.) The comparison of different modulation systems depends upon transmitter power. In the present comparison the FM carrier power was assumed to be the peak power on SSB. This was the practical limitation for the transmitter klystron in use, but other types of valve may give higher peak power as linear amplifiers than under continuous output (FM) conditions.

In order to compare the relative performance of the two systems, an SSB modulator and demodulator were developed for installation on the link. Practical filter design requirements necessitated that the 12-108 kc/s channelling equipment output (or baseband) was translated to final frequency in several stages. Fig.13 shows the elements of the system (a pilot carrier was required to correct for frequency drift in the system). As diversity equipment was not available for SSB reception, comparative tests between SSB and FM were performed without diversity in both cases. In practice the measured difference in signal-to-noise ratio was of the order indicated and subjectively there was little apparent difference between the systems.

In order to provide comparisons under low-signal conditions when the received level was near the threshold of the FM receiver, the transmitter power was reduced. It was apparent that during a fade the signal would disappear for a longer period of time in the FM case than occurred with the SSB signal, but in other respects there was no apparent superiority of performance of the SSB over the FM.

4.6 DIFFERENTIAL FADING

The bandwidth that can be usefully employed on a tropospheric scatter circuit is limited by the range of frequencies over which the sidebands will fade simultaneously. In order to investigate this problem, provision was made to radiate two carriers simultaneously from the Start Point transmitter. These carriers, which were crystal-controlled, could be spaced up to 6 Mc/s apart. At the receiving terminal, both carriers were present in the head IF amplifier, after which they were separated by connecting the two high-speed recorder channels to the same receiver and tuning the oscillators in each frequency-changing circuit to select

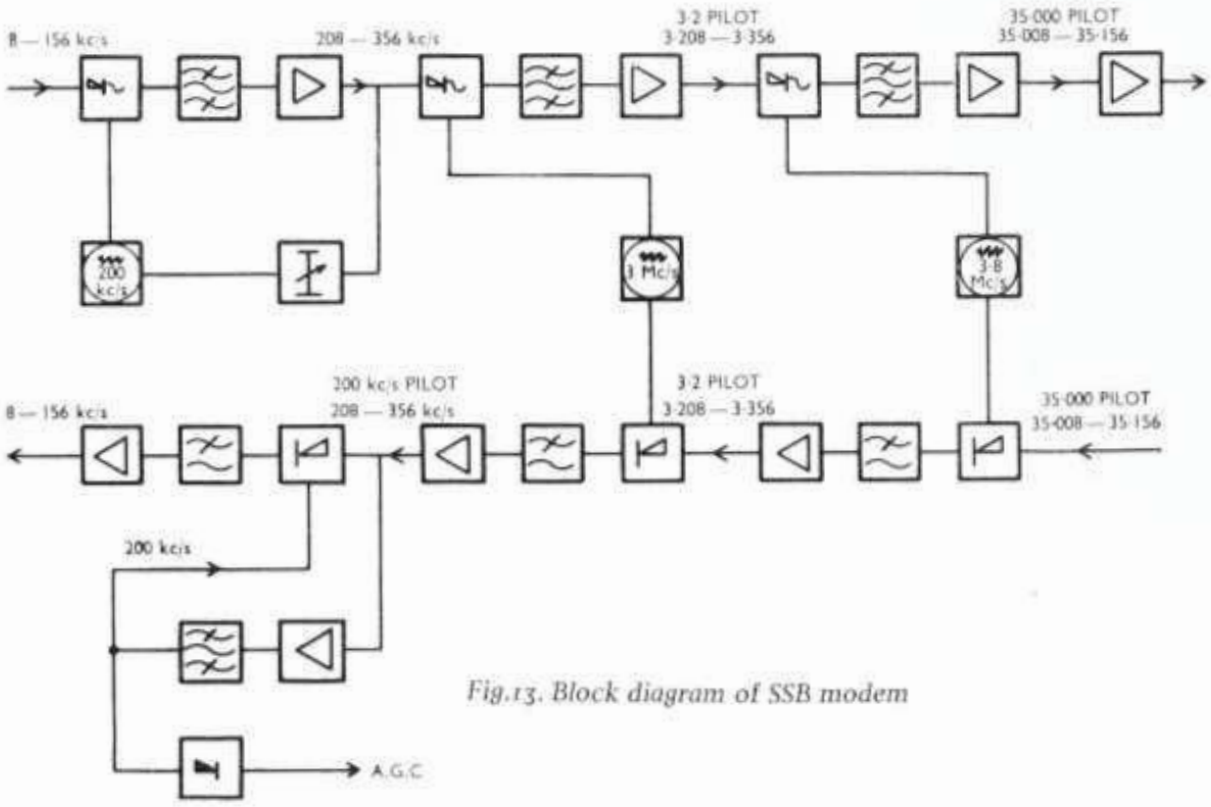

Fig.13. Block diagram of SSB modem

the appropriate frequency. Examination of the fast recording chart indicated that up to 1 Mc/s spacing, the two carriers faded simultaneously, whereas with 2 Mc/s spacing the received carriers were uncorrelated.

As an alternative to analysing the correlation of the two signals by examination of the recorder chart, it was possible to feed the two carriers to a system of counters which recorded the number and length of fades in each case, and also the number and length of coincidence fades.[4]

A further method of displaying differential fading was employed using the television frequency modulator to swing the frequency of the transmitter ± 3 Mc/s at a frequency of 1 000 c/s. At the receiver the amplitude of the received signal was displayed using the discriminator output as a time base. The display showed that many of the deep fades affected only a small part of the passband and appeared to move across it. During aircraft 'flutters' two or three fades were observed in anti-phase, giving the overall display the appearance of a sine-wave. Very

rarely did the whole passband fade out simultaneously. The 1 Mc/s bandwidth free from selective fading agrees with the figure estimated from the length of the path and the aerial beamwidths. If a wider band is required, larger aerials should be considered.

4.7 TELEVISION

During May 1959, a test card picture from a monoscope and associated synchronizing generator was transmitted from Start Point. During the period of the tests (April/May 1959) the signals received at Galleywood were quite average.

Frequency modulation was used for the television experiment because it was considered that fading would have a greater effect on an SSB transmission, and because the link could be more easily adapted for FM television. The maximum half-power bandwidth that the klystron in the transmitter could be adjusted to provide was in the region of 6 Mc/s. At the range of 200 miles this bandwidth would be subject to considerable differential fading. Despite this limitation it was decided to proceed with the tests. In order to use the restricted bandwidth to maximum advantage the highest video frequency was limited to 2 Mc/s, and the peak deviation to 1 Mc/s. With a 6 Mc/s bandwidth and a receiver noise figure of 10 dB, the receiver threshold is −117 dBW. A signal of −110 dBW at the receiver input will provide a picture with a signal-to-noise ratio of 11 dB (allowing the synchronizing-pulses to occupy 50% of the video waveform) and would appear to offer an inadequate fading margin for a reliable television picture. A received level of −100 dBW and upwards, however, would provide useable service.

At an input level of −110 dBW, the test card displayed on a monitor clearly exhibited the 2 Mc/s bars, and although the fading caused momentary disappearance of the picture from time to time, a useable picture was available most of the time. The noise was not as apparent as one would expect, probably due to the fact that the larger part of the noise power was concentrated in the higher video frequencies. A certain amount of multi-path distortion was evident at times in the form of echoes.

At signal levels of −100 dBW and above, the received picture became quite good although echoes still made their appearance and momentary disappearances of the picture still occurred, and bearing in mind that diversity was not used, the television tests were more successful than had been expected. Fig.14 (page 48) shows the received picture at Galleywood at various stages of a fade. The quality of the received picture cannot be compared with that obtainable on line-of-sight links or lines, but may be acceptable in cases where tropospheric scatter is the only means of transmitting a television picture. The provision of an audio channel to accompany the television picture would, however, present some difficulty. The use of quadruple diversity would affect a considerable improvement in the reduction of fades; however, the design of a diversity combiner for television gives rise to a number of problems.

4.8 AIRCRAFT FLUTTER

It would be wrong to attribute too much importance to the fading phenomenon caused by multi-path propagation when the signal reflected from an aircraft interferes with the normal tropospheric scatter signal. This occurred very often during the working of the experimental link because the path passed through one of the highest aircraft density areas in the country, including both Farnborough experimental airport and London Airport. Despite the frequency of occurrence, the fading at no time threatened telephone intelligibility, and the diversity arrangement gave the same protection against aircraft flutter as against any other rapid fading due to multi-path propagation. On telegraphy the same considerations apply as for ordinary fast fading.

The rapid fading associated with aircraft reflections occurs frequently with television broadcasting, and in this case the effect is observed when the aircraft is near to the receiving aerial. With tropospheric scatter transmissions however, the narrow aerial beams at transmitter and receiver effectively confine the phenomenon to the areas in which the aircraft is in both of the beams simultaneously (i.e, the common volume). Calculation of reflected power indicates that this would be expected, and the observed maximum rate of flutter of about 20 cycles/second, combined with the likely maximum aircraft speeds, confirms this result.

Fig.11 includes a signal strength recording in which aircraft reflections produce very deep fading at times, indicating that the reflected signal was nearly equal to the normal tropospheric scatter signal. The beat is due to the relative change of path length due to the aircraft velocity; if the aircraft flies across the path, the flutter frequency drops to zero, rising again as the aircraft passes out of the other side of the beam.

The movement of aircraft was observed with radar at the time when flutter occurred. It was often difficult to identify with certainty the aircraft causing a particular flutter, but several cases were observed when aircraft caused flutter when they crossed the beams near the mid-point of the path. A height finder was used to confirm that aircraft crossing the path at 40 000 feet never caused the effect, being above the maximum height of the beam.

Observations with pulses radiated from Start Point and received at Galleywood showed that the received pulse amplitude fluttered in the same way as continuous radiation when an aircraft was present; double pulses were never observed. This confirms the suggestion that the aircraft must be in the same region as the scatter patch, since a reflection from outside this area would produce an observable path difference, with two steady received pulses.

5 CONCLUSIONS

The measured signal strengths obtained with this experimental link agree in the main with the predicted values. The median signal strength variation was as high as 80 dB during the year, and receivers must be designed to handle this condition.

With the aerial gains and transmitter power used, reliable communication can be provided with a 24-telephone-channel system over a 200-mile path for 99% of the time, providing that diversity reception is used and there are no high obstructions in the terrain covered by the path. Experience in operating the link has proved a necessary preliminary to developing satisfactory production equipment, and in system planning. The results apply, of course, to operation in a temperate zone and do not necessarily apply to tropical or arctic regions.

For operational links it is desirable to use wherever possible a quadruple-diversity system using two transmitters and four receivers at each terminal. In addition to the improved performance due to high-order diversity, the reliability is greatly increased as half the equipment at each terminal operates as an active stand-by.

The future application of tropospheric scatter communication is largely influenced by economic considerations. The highest quality communication will continue to be provided by line-of-sight links, where the path permits the installation of repeaters, but for paths over sea or inhospitable terrain, the quality provided for medium-capacity services by tropospheric scatter propagation should be adequate for most purposes. Although the aerials and high-power transmitters are more costly than for line-of-sight systems, the elimination of six or seven intermediate repeating stations provides a compensating saving, so that the cost difference may not be great.

References

1 *Proc. Inst. Radio Engrs.* Vol. 43 (October 1955).
2 *Proc. Inst. Elect. Engrs.* Vol. 105, Part B (1958).
3 C. L. MACK: 'Diversity Reception in UHF long range communications'. *Proc. Inst. Radio Engrs.* Vol. 43, No. 10 (1955).
4 G. L. GRISDALE, J. G. MORRIS and D. S. PALMER: 'Fading of long distance radio signals'. *Proc. Inst. Elect. Engrs.* Vol. 104, Part B (1957).
5 S. FEDIDA: 'Some design considerations for links carrying multi-channel telephony'. *Marconi Review* Vol. 18, (1955).

G. L. GRISDALE, born in 1914 in London and entered Queen Mary College, London University, in 1931, where he did research work into measurement of dielectric losses. He joined the Communications Receiver Section of the Marconi Company in 1937. In 1950 he transferred to research and in 1952 he was appointed Leader of the Communication and Direction Finding Research Section. In 1954 he took charge of Communications Research Group which later became the Communications Advanced Development Group and has been concerned with a number of advanced development projects, including investigation on diversity reception, single-sideband communication and tropospheric scatter technique.

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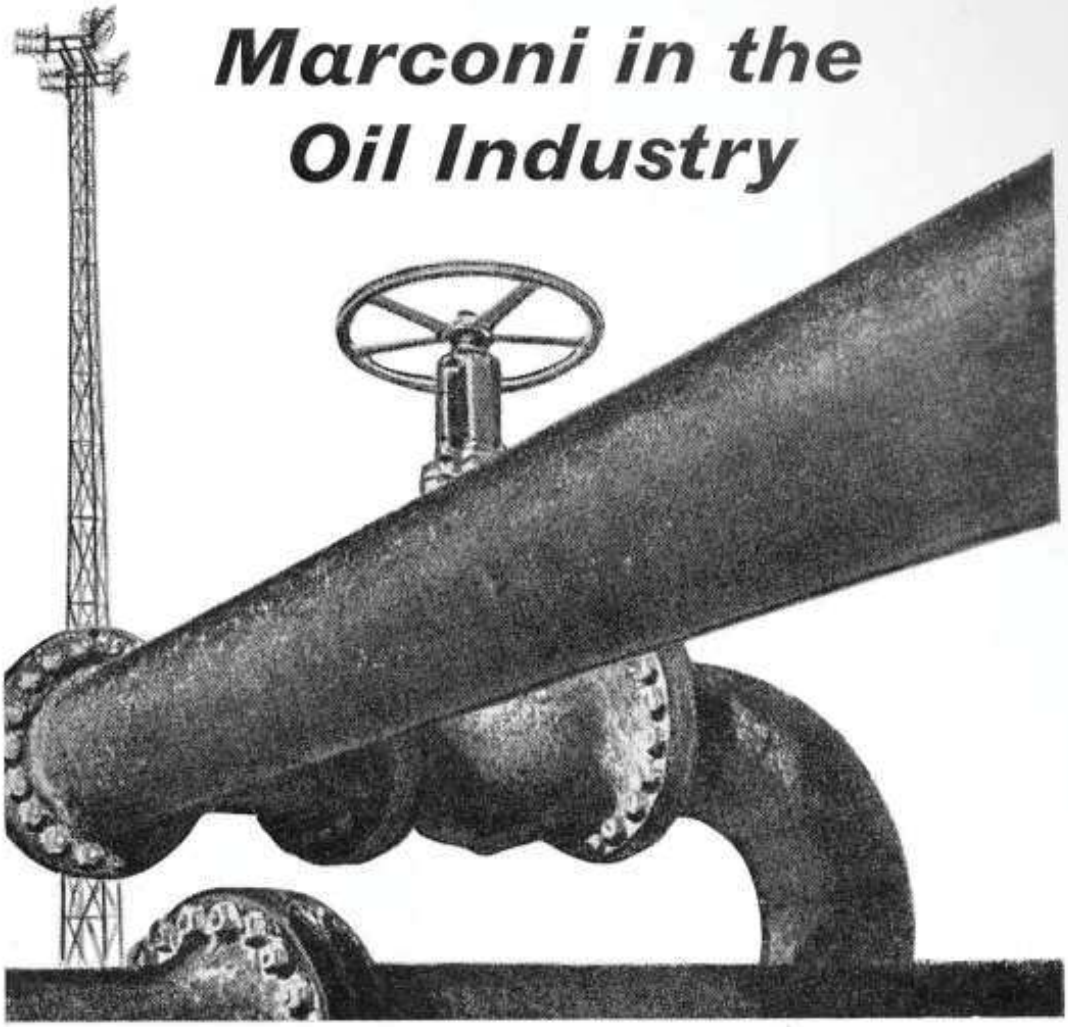

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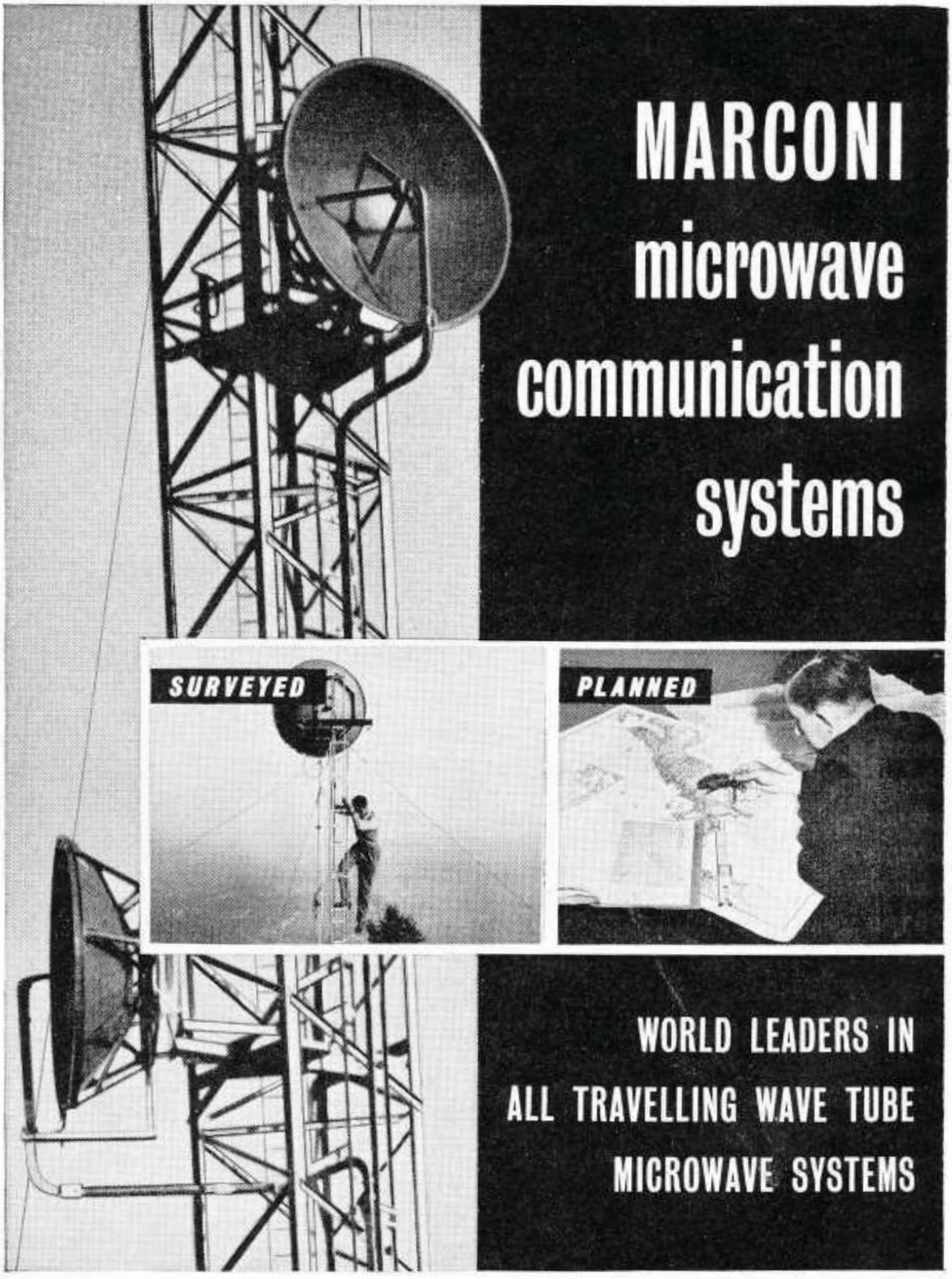
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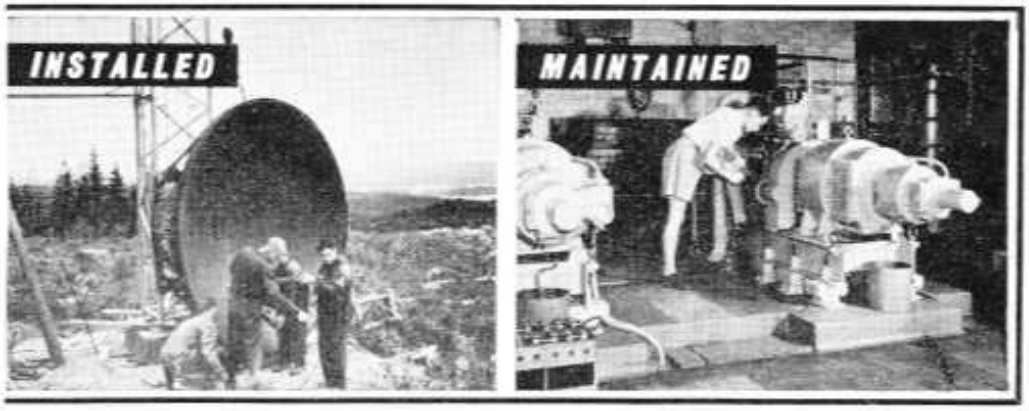

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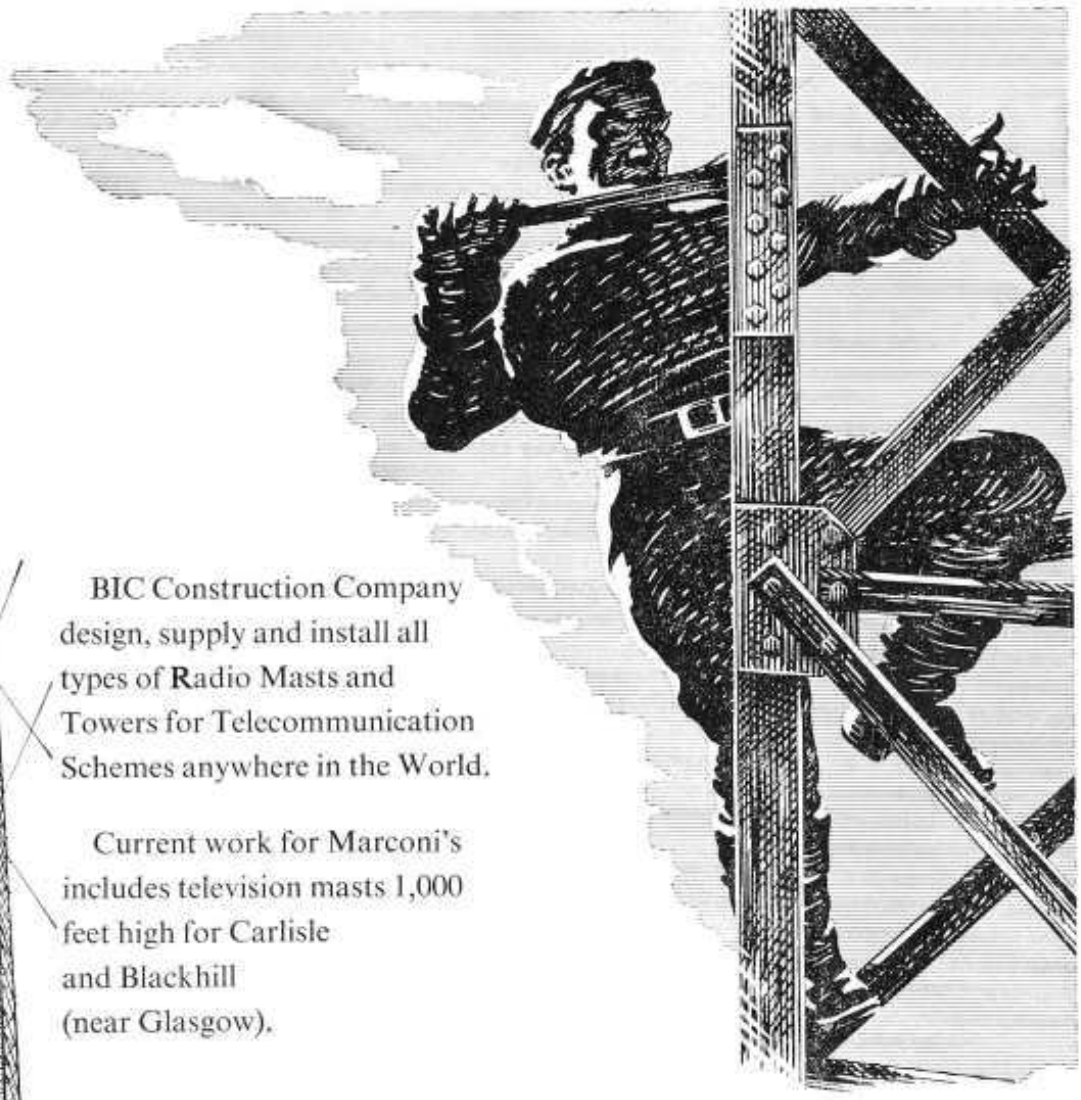

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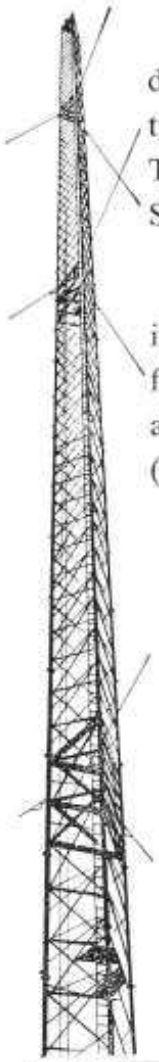

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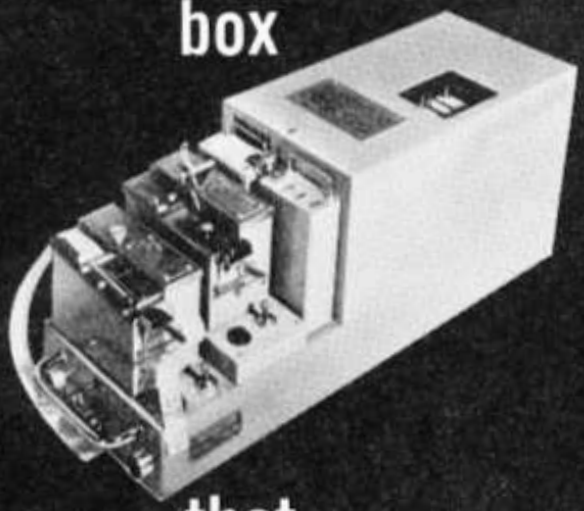

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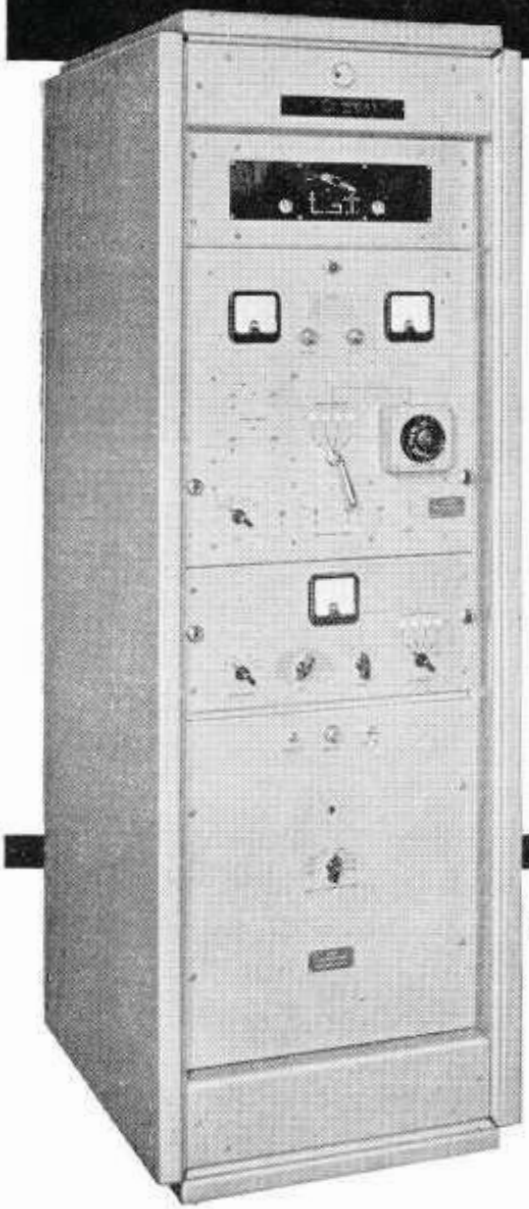

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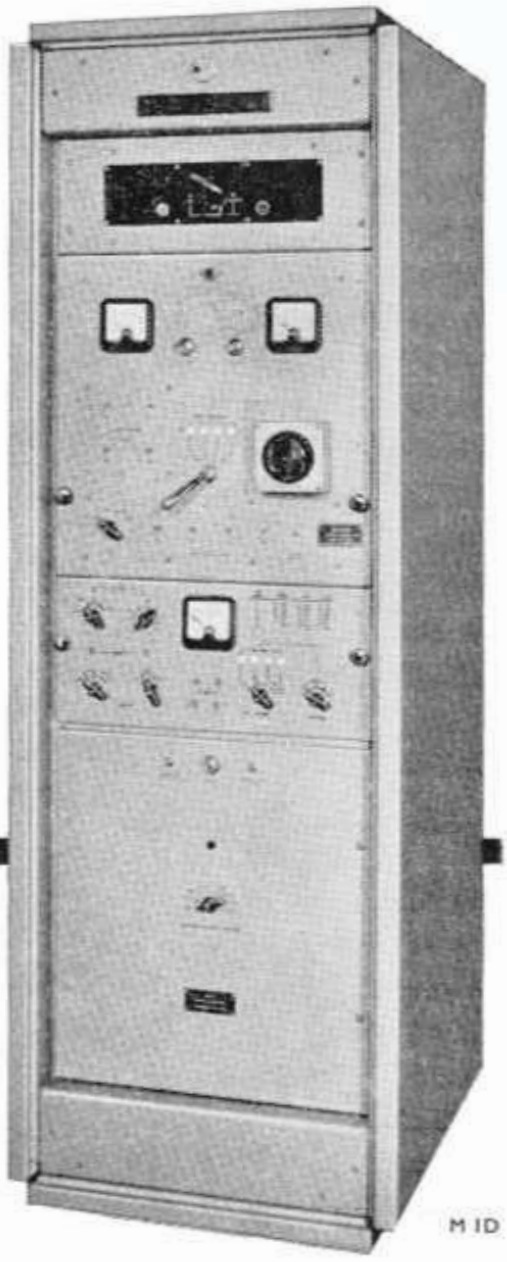

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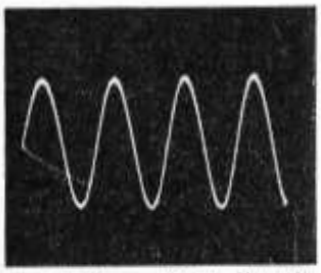
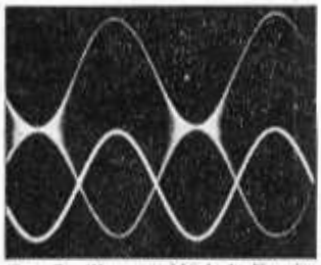
MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED · CHELMSFORD · ESSEX · ENGLAND

M ID



Test Oscillogram 15 Kc/s Unmodulated Carrier showing good waveform.



Test Oscillogram 320 kc/s Carrier modulated at 400 c/s—audio source on lower trace shows fidelity.

MARCONI

Standard Signal Generator

TYPE TF 867

UNDISTORTED 100% MODULATION

AM WITHOUT FM

WIDE RANGE
15 kc/s to 30 Mc/s on 15 ft. high-discrimination full-vision scale.

CRYSTAL ACCURACY
0.01% with built-in 1 Mc/s harmonic source.

HIGH OUTPUT
4 volts down to 0.4 microvolts.

FLEXIBLE MODULATION
Internal 400 and 1,000 c/s; external 50-10,000 c/s within 1 dB.

Also incorporated: Automatic level control, overall negative feed-back from r.f. output to modulation input, modulation monitoring by dual rectification, and variable impedance termination with animated diagram.

MARCONI INSTRUMENTS

A signal generator also ideal as a video oscillator for wide-band television systems.

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTFORDSHIRE
TELEPHONE: ST. ALBANS 56161
WORLD-WIDE REPRESENTATION

TC 107R